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Produced by the NASA Center for Aerospace Information (CASI)

space station systems analysis study

program review

volume 2 program review report

(NASA-CR-161231) SPACE STATION SYSTEMS ANALYSIS STUDY. VOLUME 2: PROGRAM REVIEW REPORT Final Report (Grumman Aerospace Corp.) 105 p HC A06/MF A01 CSCL 22B
N84-31264
Unclas
G3/18 00945

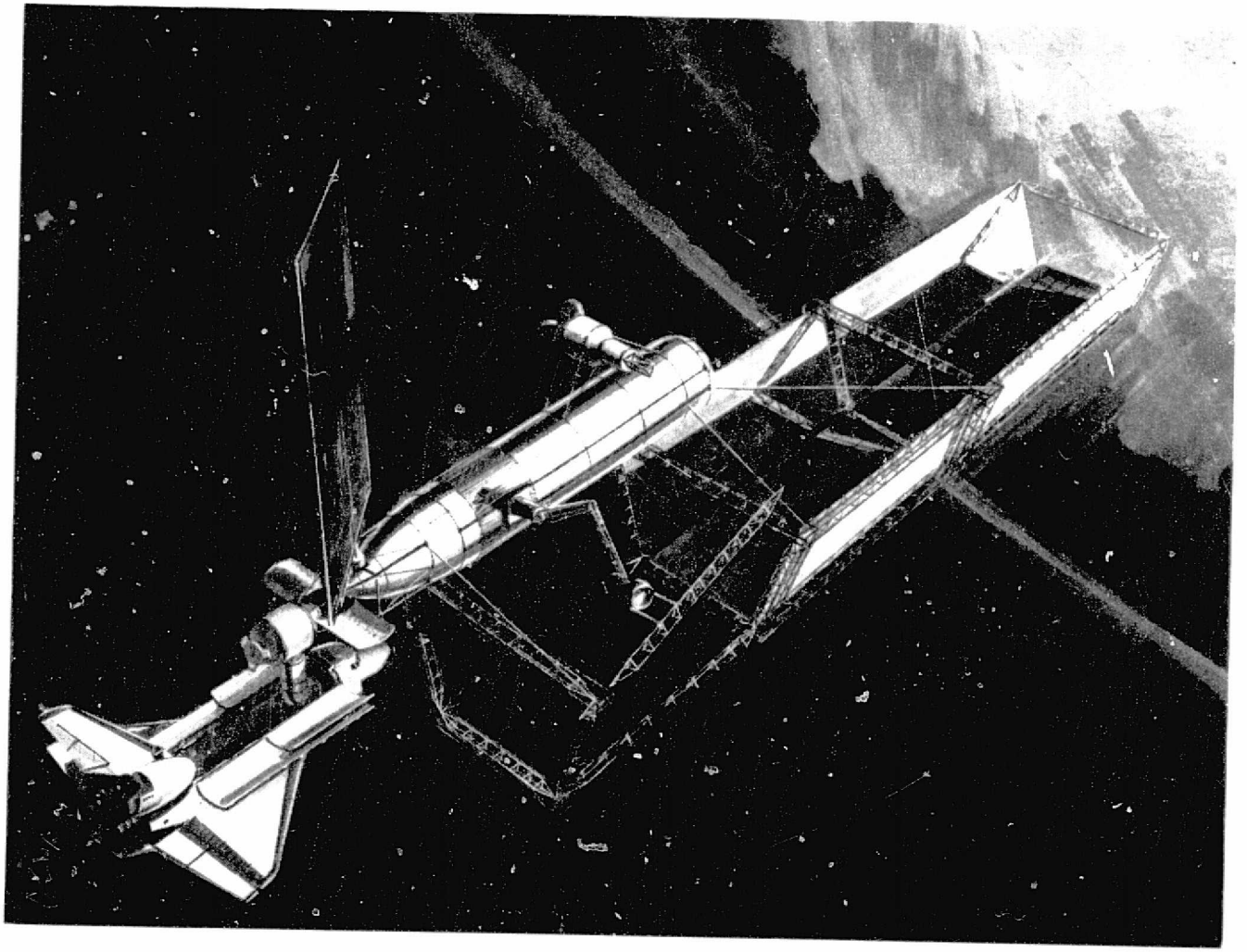
SEP 1984
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

19-20 April 1977

GRUMMAN

space station systems analysis study

program review



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VOLUME 2 PROGRAM REVIEW REPORT

19-20 April 1977

Report No. NSS-SS-RP016

Contract No. NAS8-31993

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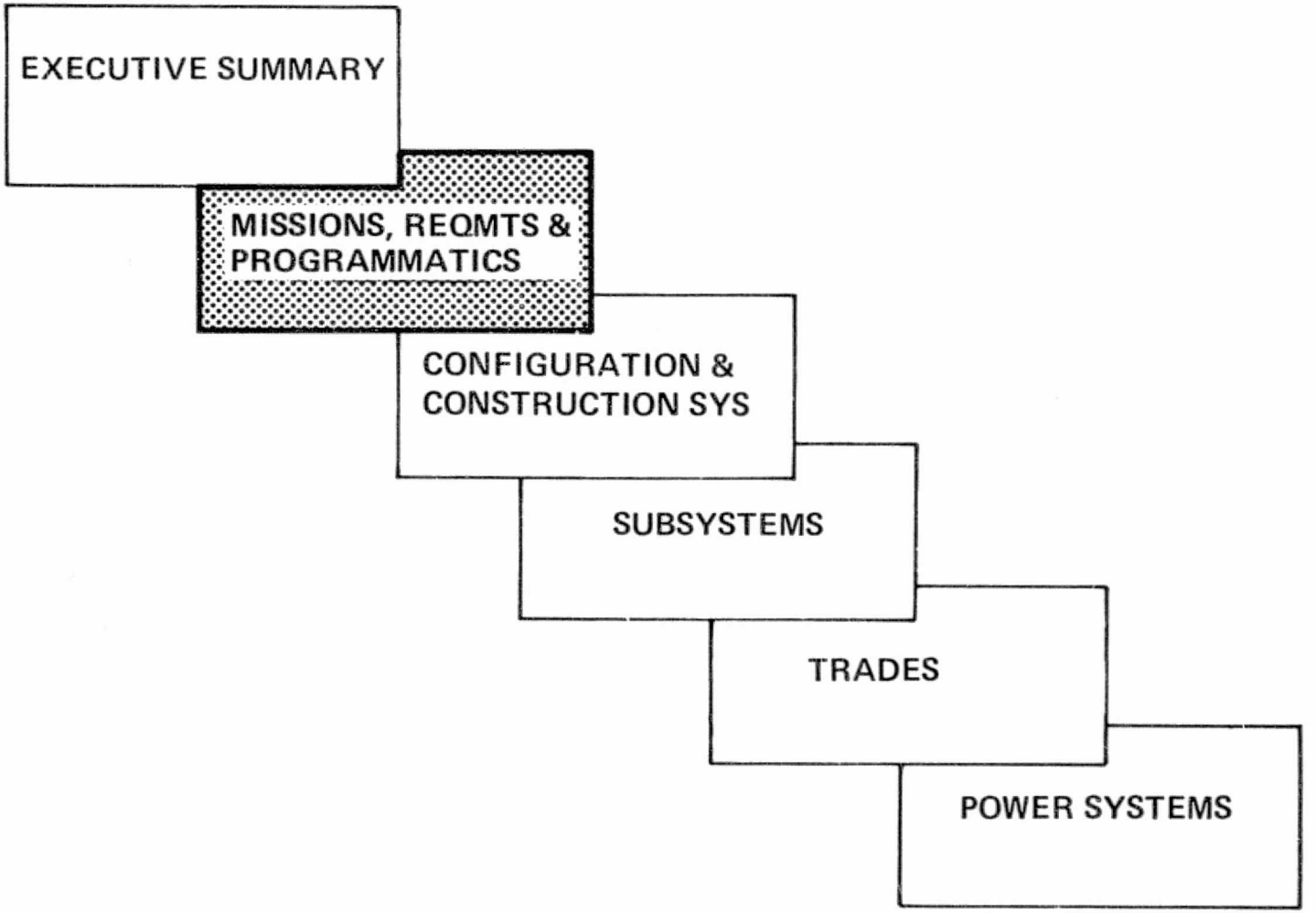
AGENDA SPACE STATION PROGRAM REVIEW MEETING
19 APRIL 1977



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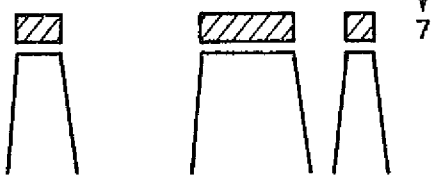
K-401B

TRANSITION FROM TENDED TO MANNED

TRANSITION GOVERNED BY
- SUSTAINED MANNING LEVELS
- ONSET OF MANNED GEO. OPS.

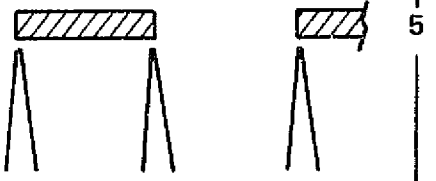
TENDED MODE

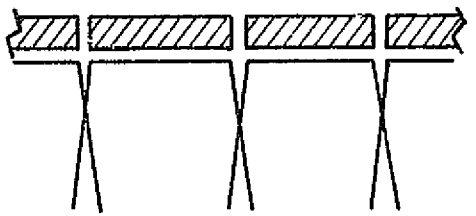
MAX CREW
(INCL ORB. SPECIALISTS)



MANNED MODE

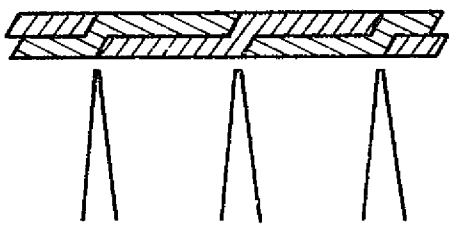
MAX CREW





"RENT" IF ORB. KEPT AT
PLTFM > 7 DAYS/FLT
$0.38M/DAY

(365-4x7) x 0.38 = $128M/YEAR



10 AT 4 FLTS/YEAR
15 AT 6 FLTS/YEAR
20 AT 8 FLTS/YEAR

COST OF HABITATION FAC.
~ $800 M.

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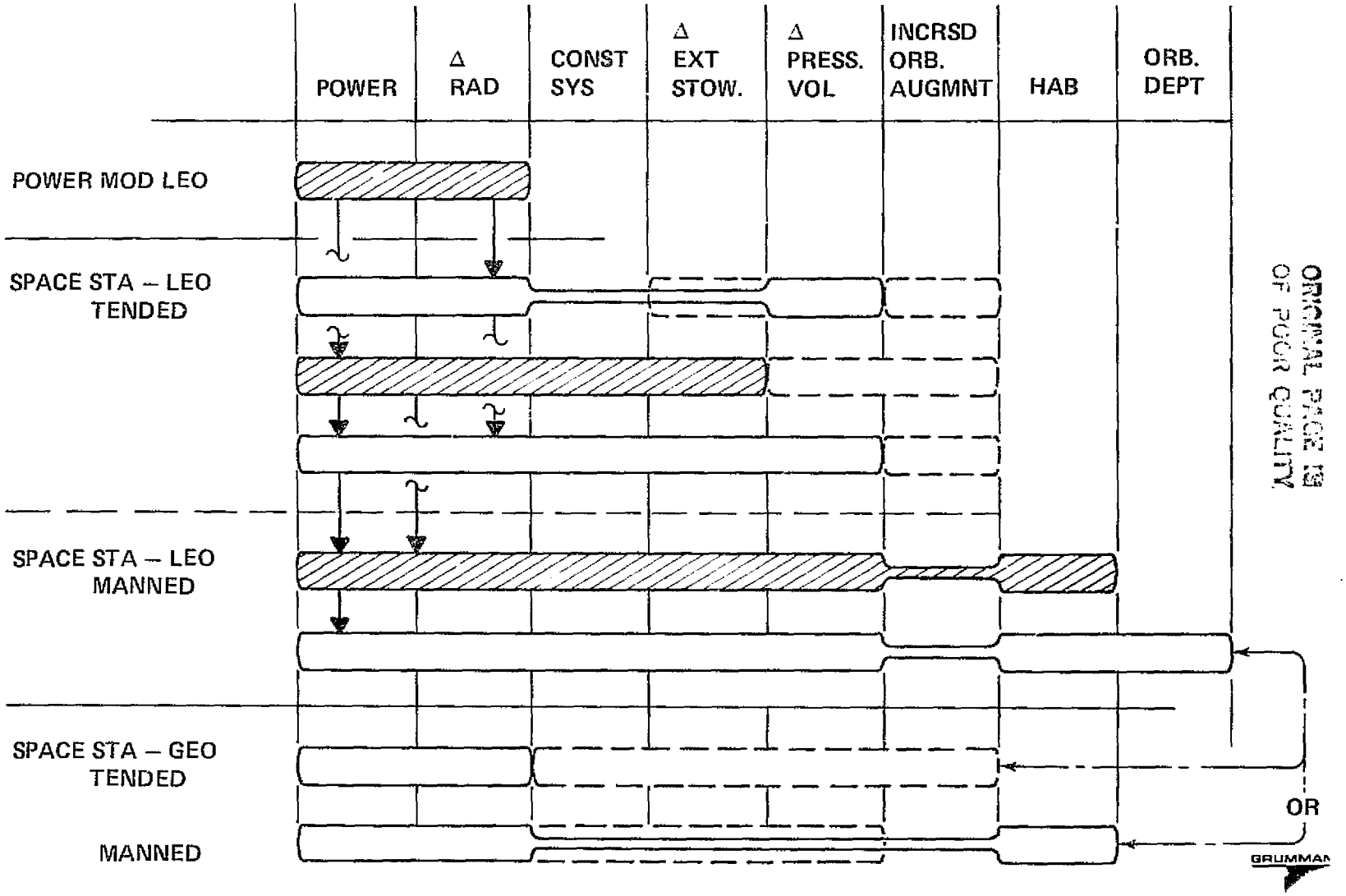
JG-402

SPACE STATION – MAJOR GROWTH OPTIONS



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JG-404

DISTINCTION BETWEEN INCREASED ORBITER AUGMENTATION & HABITATION

	TENDED	MANNED
• LIFE SUPPORT	?	√
• WASTE MGMT	?	√
• HYGIENE	?	√
• COOKING	?	√
• SLEEPING/STOWAGE ROOM	?	√
• RECREATION	?	√
• COMMUNICATIONS	?	√
• COMPUTER	?	√

OPTIONAL "INCREASED ORB. AUGMENTATION"
- CREW COMFORT
- CREW EFF

MANDATORY "HABITATION" PROVIDES:
- REDUNDANCY
- ROUTINE MAINTAINABILITY

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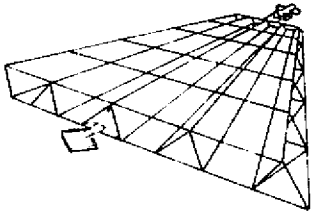
JG-405

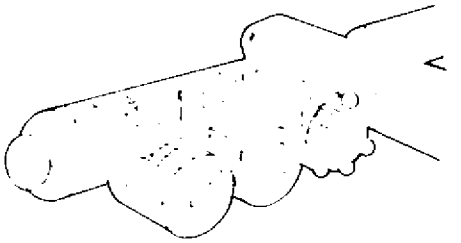
MISSION CATEGORIES

- SOLAR POWER SATELLITE DEVELOPMENT
  - INCREMENTAL STEPS

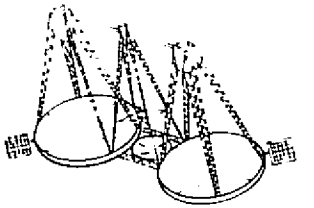


MISSIONS FOR BENEFIT ON EARTH

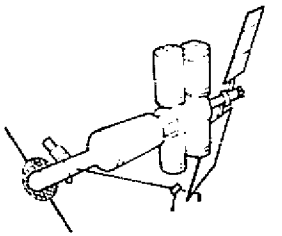
- SPACE MANUFACTURING
  - HIGHER PERFORMANCE MATERIALS
  - EXTENDED APPLICATIONS



- PUBLIC SERVICE PLATFORM
  - GROUPING MULTIPLE FUNCTIONS FOR ECONOMY
  - LARGE ANTENNAS



- BENEFICIAL SCIENTIFIC MISSIONS
  - SOLAR-TERRESTIAL OBSERVATIONS
  - LIFE SCIENCES
  - OTHERS



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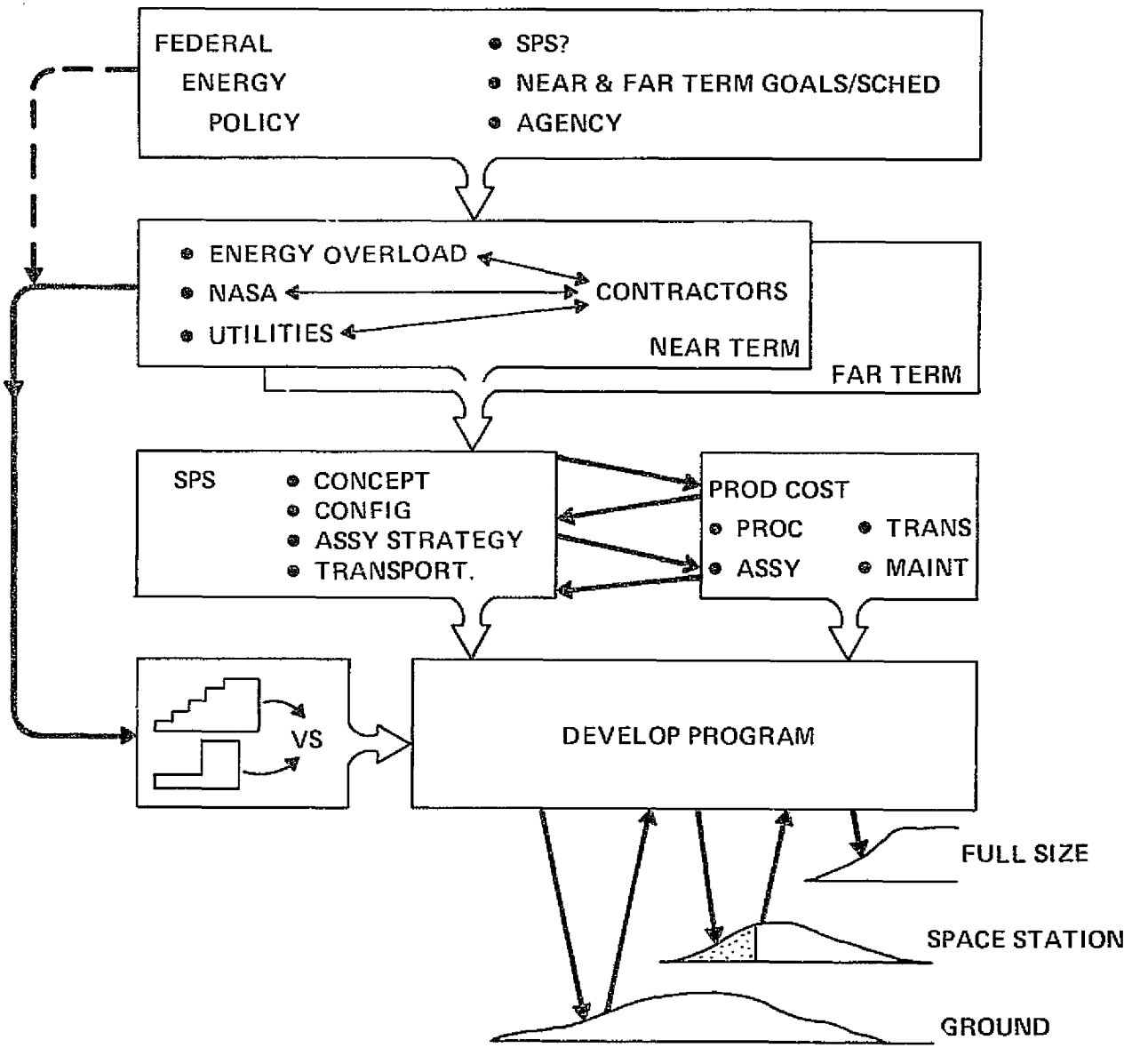
SPS DEVEL PROGRAM/SPACE STATION RELATIONSHIP



JG-401

SPACE STATION STUDY – CURRENT FULL SIZE SPS DEFINITION

CONCEPT POWER SOURCE	C:R	R.F.GEN. AMPL.	R.F.GEN. KLYST.	R.F.GEN. S.S.	SIZE (PWR DELVD)	ASSY SITE LEO	ASSY SITE MIXED	ASSY SITE GEOS	SCHEDULE MAJ. GO-AHEAD DECIS.	SCHEDULE IOC
PHOTOVOLT. CdSULPHIDE	1:1				5 GW				'87	'95
Si	2:1									
GaAs	7:1									
THERMAL-BRAYTON	2000:1									

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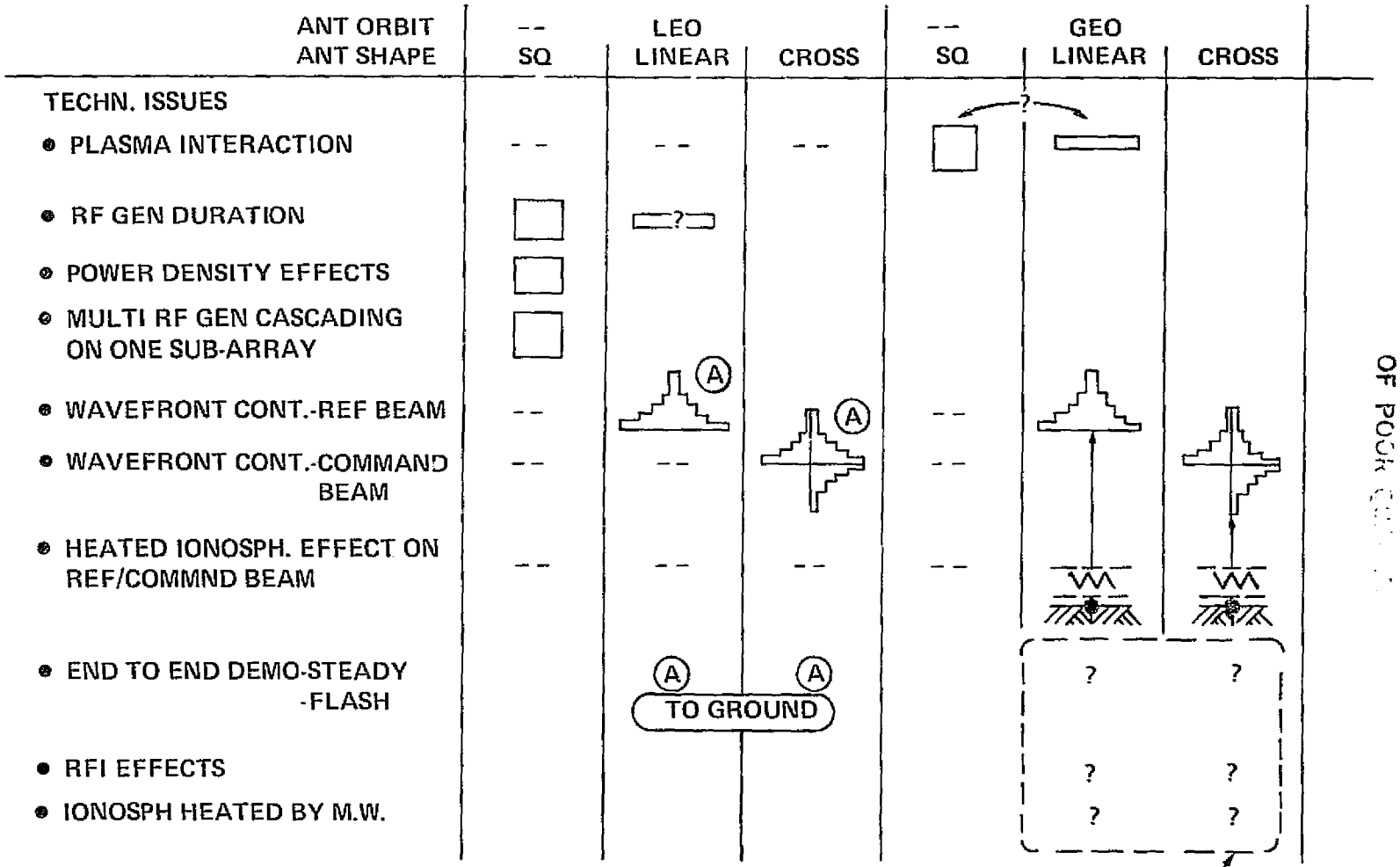
JG-461

SPS DEV
MICROWAVE ISSUES & DEV. ANTENNA OPTIONS



LEGEND (A) -- TRANSMISSION TO FREE FLYER IN SAME ORBIT

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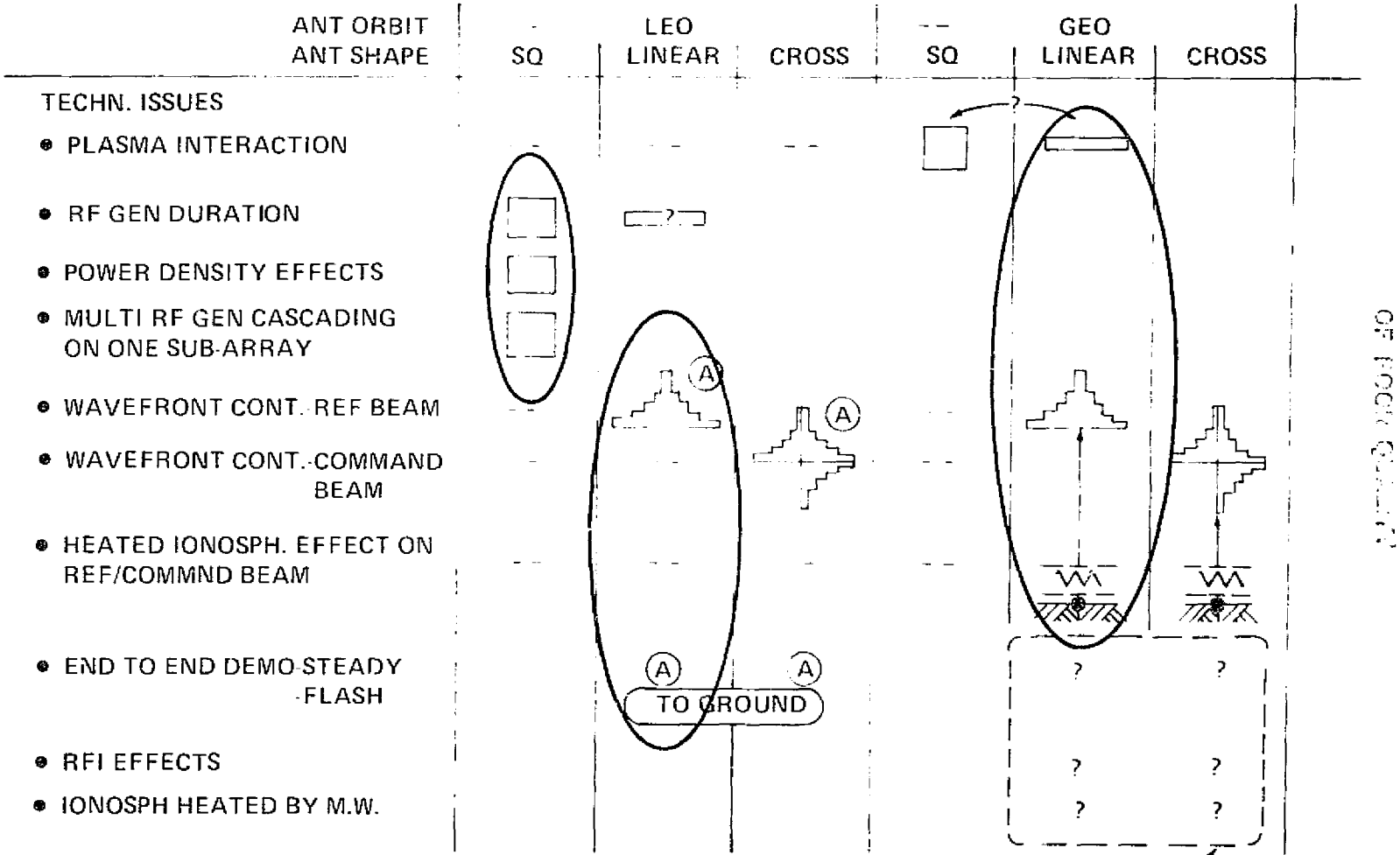
JG-433

SPS DEV

MICROWAVE ISSUES & DEV. ANTENNA OPTIONS



LEGEND (A) - TRANSMISSION TO FREE FLYER IN SAME ORBIT

SPDA SIZE IS A SIGNIFICANT PROBLEM

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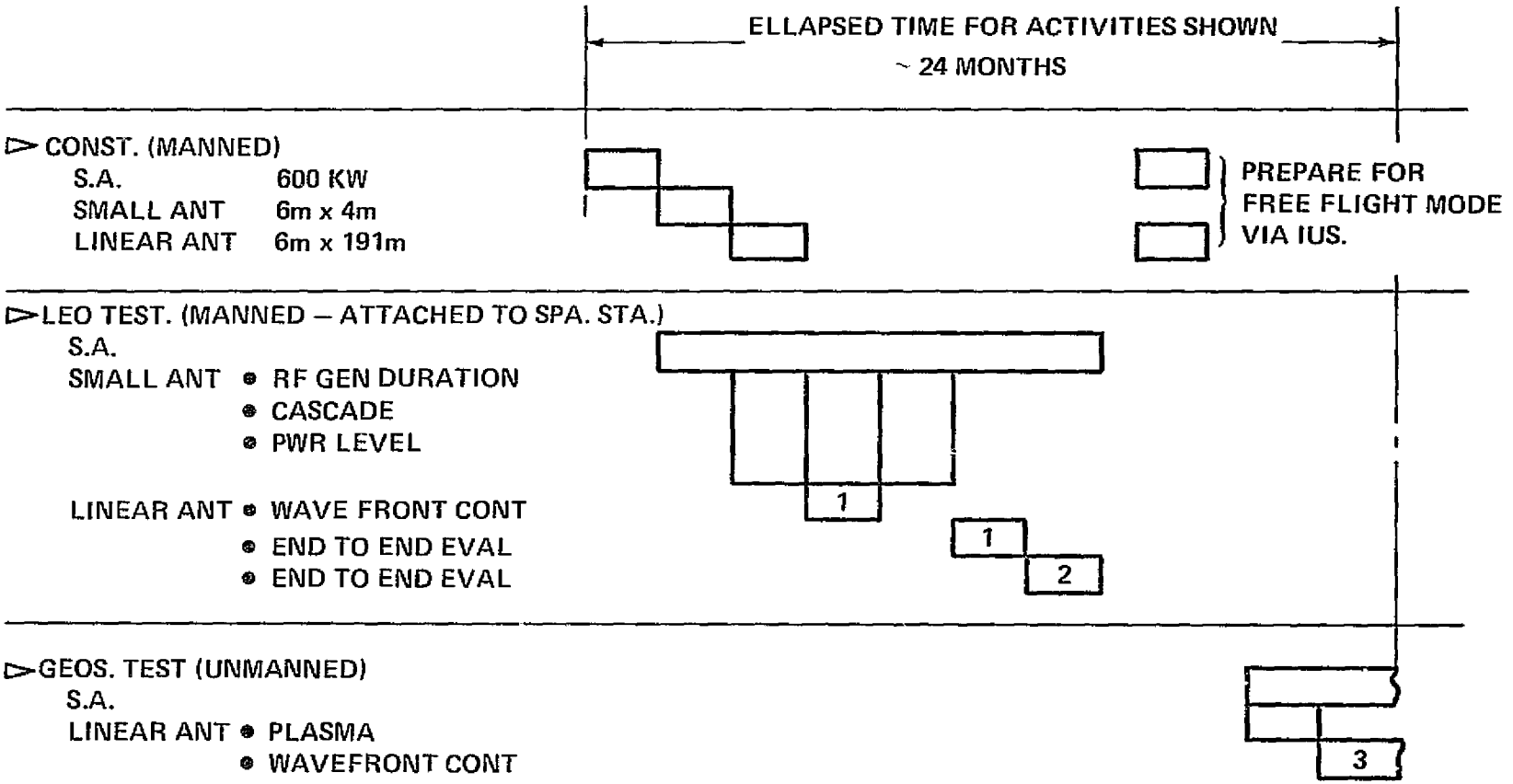
JG-434

600 Kw SPDA PROGRAM



NOTE ① – TRANSM. TO FREE FLYING RCVR – ORBITER (OR BACK TO SPA. STA.)
② – TRANSM. TO GROUND ~ ID SECS
③ – TRANSM. TC GROUND CONTINUOUS

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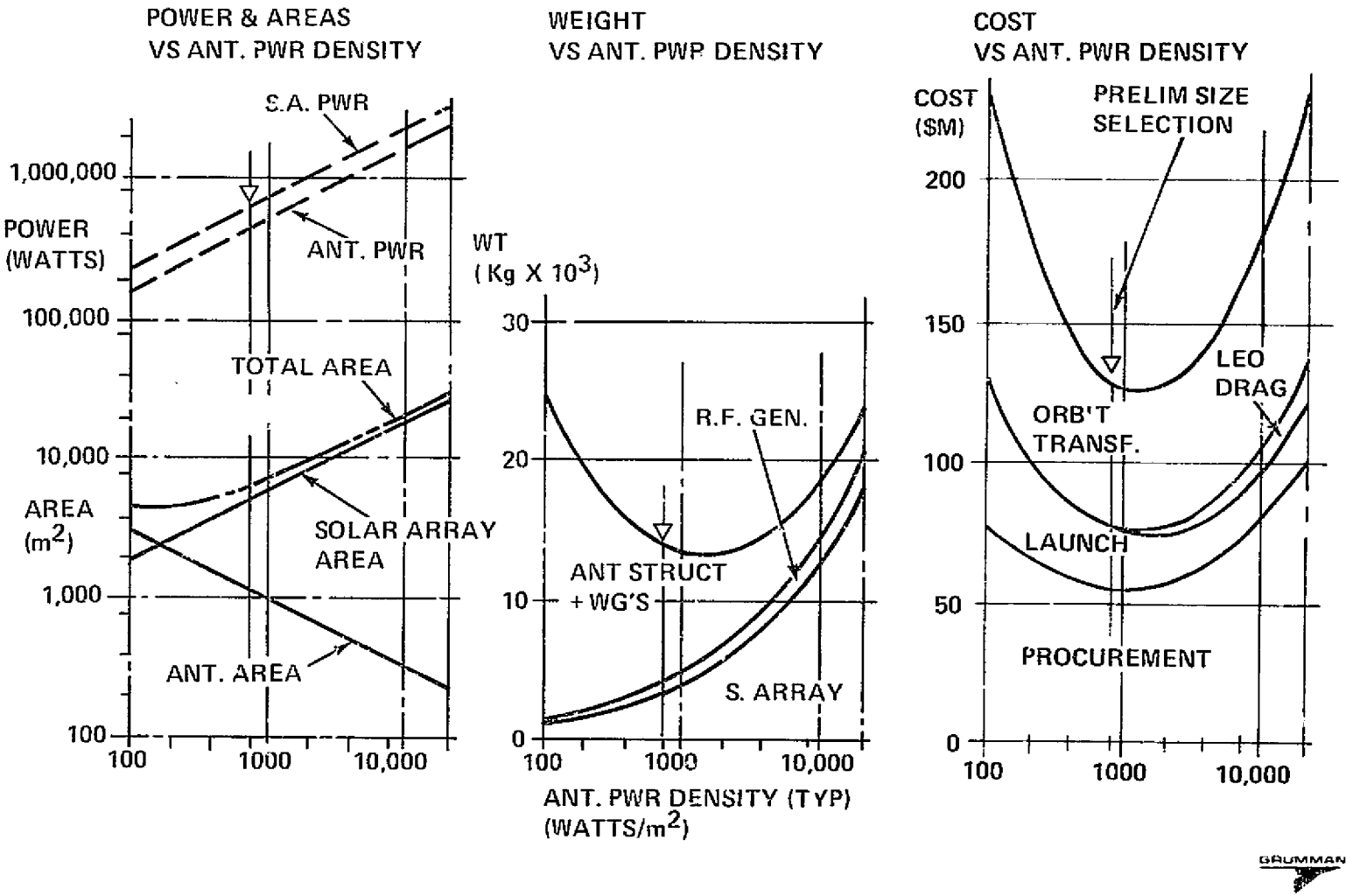
JG-468

SPDA CAPABLE OF TRANSMITTING POWER TO GROUND FROM 400 Km. ALT. SIZING CONSIDERATIONS



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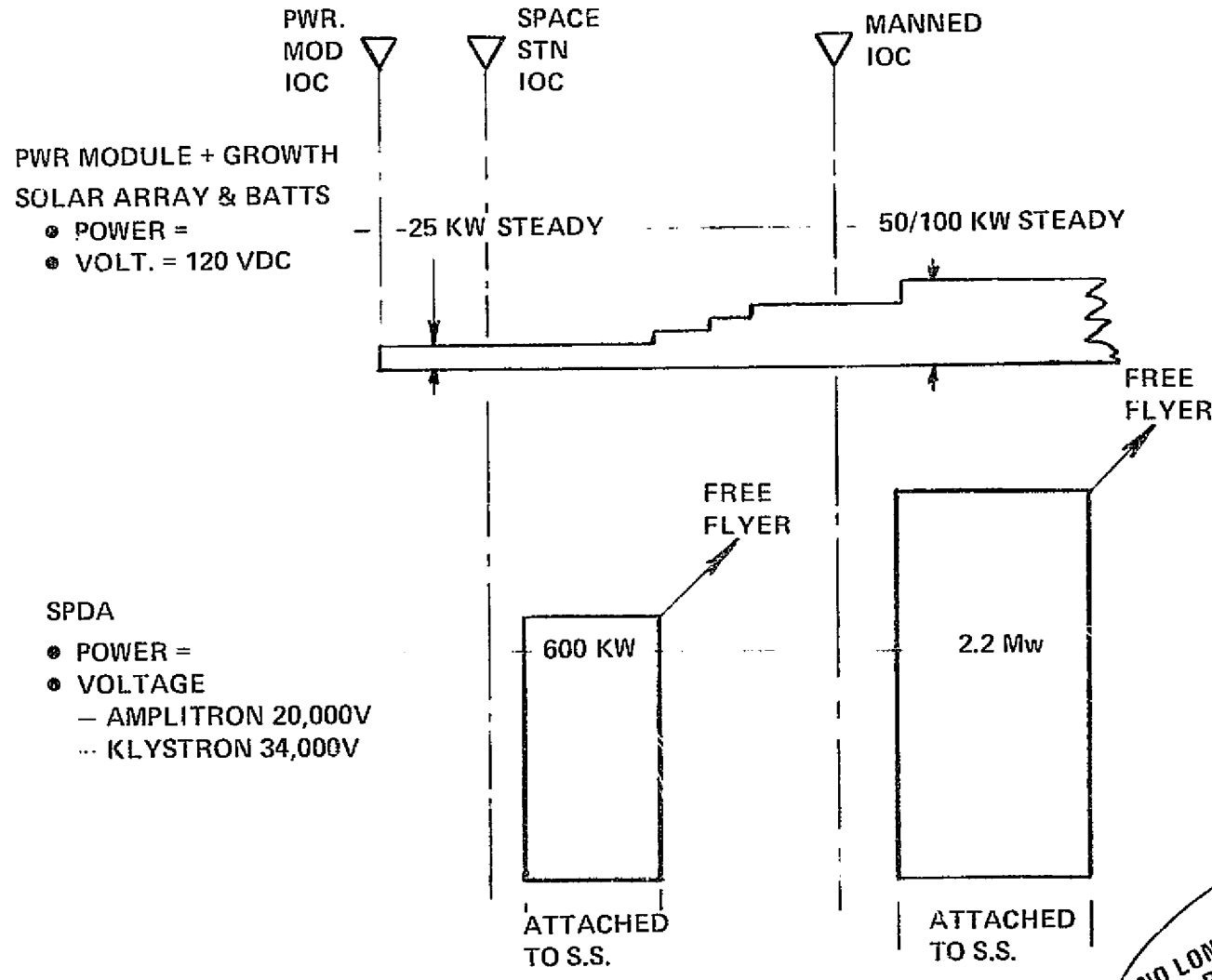
JG-435

NEW SPACE STATION POWER SUPPLY APPROACH



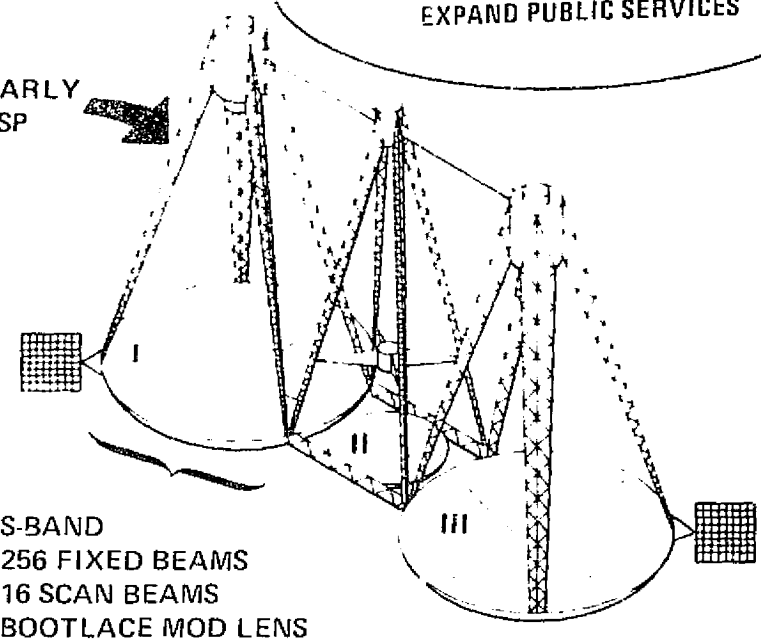
JG-462

PUBLIC SERVICE PLATFORM

AN INTEGRATED PUBLIC SERVICE CONCEPT

WIDE RANGE OF SERVICES COULD BE PERFORMED	
• VOICE/DATA	
– PERSONAL COMM	I
– POLICE COMM	I
– DISASTER CONTROL	I
– VOTING/POLLING	I
– ETC	I
• VIDEO/DATA	
– ADVANCED TV	II
– TELECONFERENCING	II
– ELECTRONIC MAIL	II
– NATL INFO SERVICE	II
– ETC	II
• DETECTION/CONTROL DATA	
– NUCLEAR FUEL LOCATOR	III
– EARTHQUAKE DETECTION/PRED	III
– WATER AVAILABILITY INDIC	III
– VEHICLE SPEED CONTROL	III
– BURGLAR ALARM/INTRUSION DET	III
– ETC	III

BROAD OPPORTUNITY FOR CAPITALIZING ON SPACE CONSTRUCTION BASE TO GREATLY EXPAND PUBLIC SERVICES



S-BAND
256 FIXED BEAMS
16 SCAN BEAMS
BOOTLACE MOD LENS
150,000 ELEMENTS

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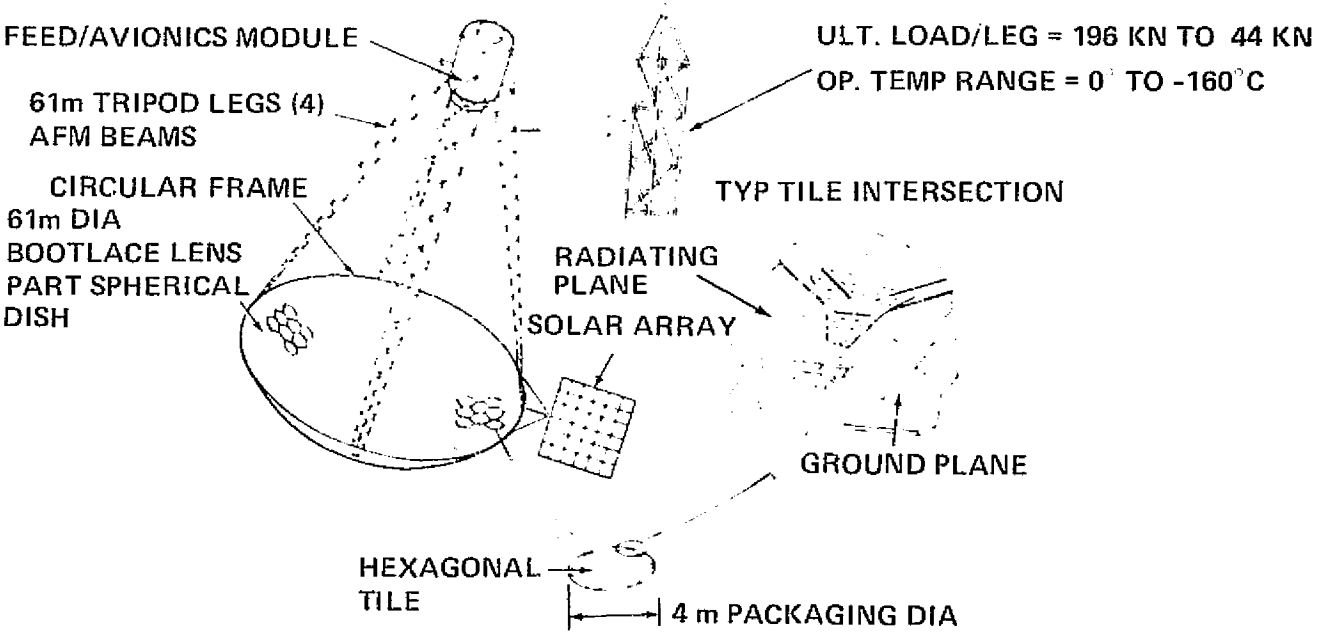
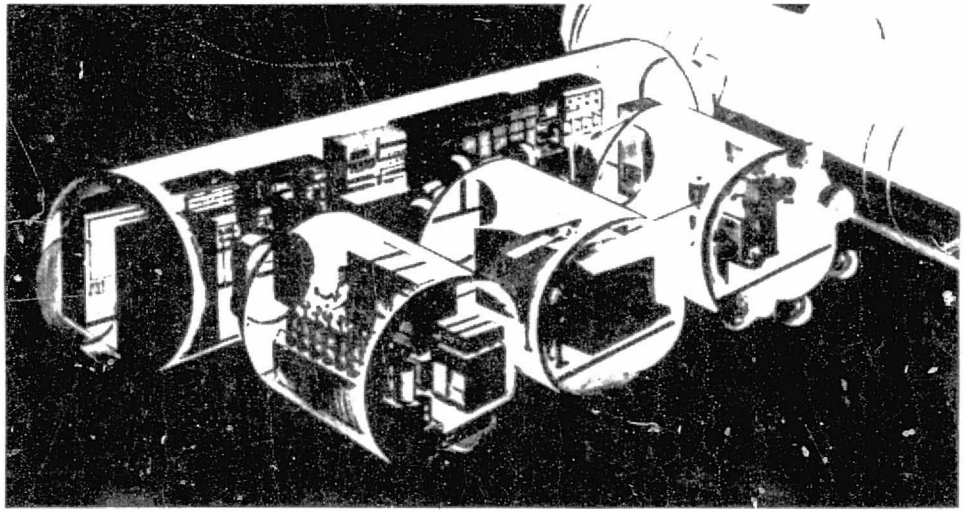
PSP INITIAL ASSEMBLY



WEIGHT DATA (Kg)	
ANT. APERTURE	
• LENS PANELS	15,568
• APERTURE RIM	1,650
FEED SUPPT. STRUCT.	1,500
FEED MODULE	2,643
SOLAR ARRAY	600
	21,961
CONTING.	5,490
DRY WT.	27,451

F-406

SPACE STATION REQUIREMENTS FOR SPACE MANUFACTURING MODULE



PROCESS	SEPARATION	TISSUE CULTURING	DIR. SOLID.	CRYSTAL GROWTH
PRODUCT (TYPICAL)	KIDNEY CELLS	UROKINASE	MAGNETS	SILICON RIBBON
RAW MAT REQD (KG/YR)	500	6 – 10	9100	2290
EXPEND. REQD (KG/YR)	1290	2300	300	610
OUTPUT (KG/YR)	6 – 10	2	9100	2290
HDWRE MASS (KG)	600	900	800	707
CONT. ELEC POWER (KW AV)	5.1	0.2	4.6	4.2
MANPOWER REQD (HRS/DAY)	< 2	< 3	< 2+1 DAY/MO	1 DAY/MO

NOTE: EACH PROCESS REQUIRES A 4 x 4m MODULE, COOLING FROM EC/LSS & CONTROL COMPUTER WITH PROCESS FEEDBACK

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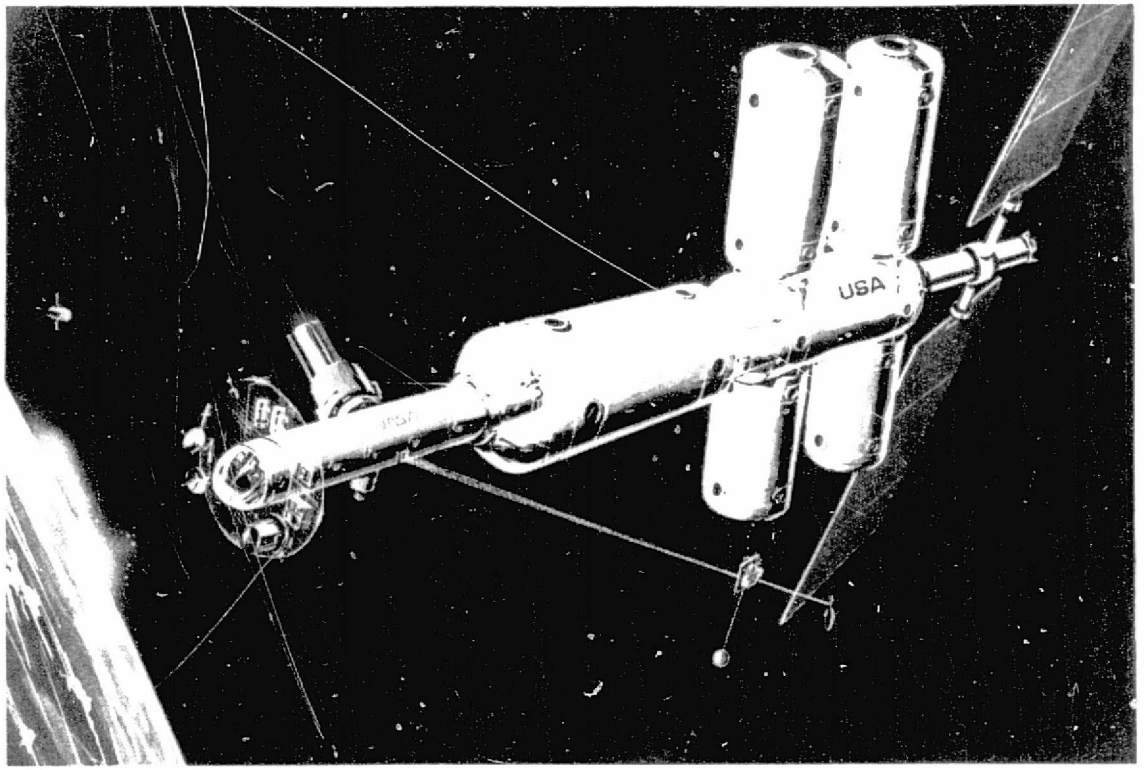
F-407

SPACE STATION REQUIREMENTS FOR SOLAR TERRESTRIAL OBSERVATORY



MEAS AREA	EARTH		ATMOSPHERE		MAGNETOSPHERE		SOLAR	
400 KM ORBIT INCL (DEG)	28.5	55	28.5	55	28.5	55	28.5	55
EQUIPMENT MASS (KG)	–	1500	300	800	–	8100	4850	4850
EQUIPMENT VOL (M^3)	–	5	3	4	–	4	9	9
POWER REQD (KW)	–	1.4	1	1.2	–	10	0.6	0.6
MANPOWER REQD TO								
• CONDUCT EXP	–	0	<1	<1	–	<1	<1	<1
• MAINTAIN EXP	–	<1	0	0	–	0	0	0

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F-408

TENDED MODE/MANNED MODE OPTION
SPACE STATION SYSTEM PROGRAM

PROGRAMMATIC GROUND RULES

- INITIAL POWER MODULE ATP FY '79
- ATP DELTA STATION FY '80
- IOC INITIAL POWER MODULE FY '83
- IOC CONSTRUCTION SYSTEM FY '84
- MAJOR SPS DECISION END '87
- SCHEDULE THRU '87

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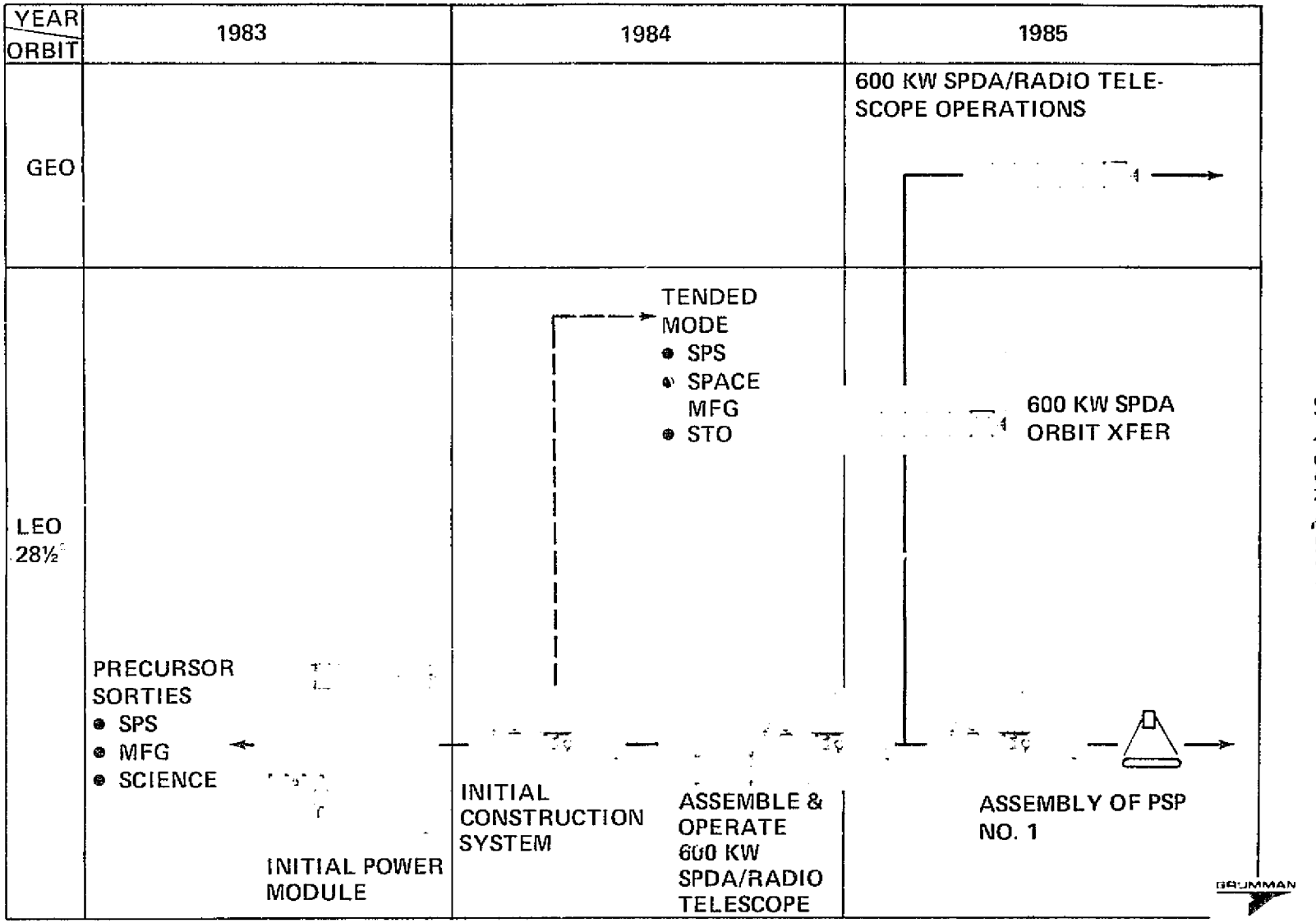
G-415

OPTION – TENDED MODE/MANNED MODE – SPACE STATION SYSTEM PROGRAM



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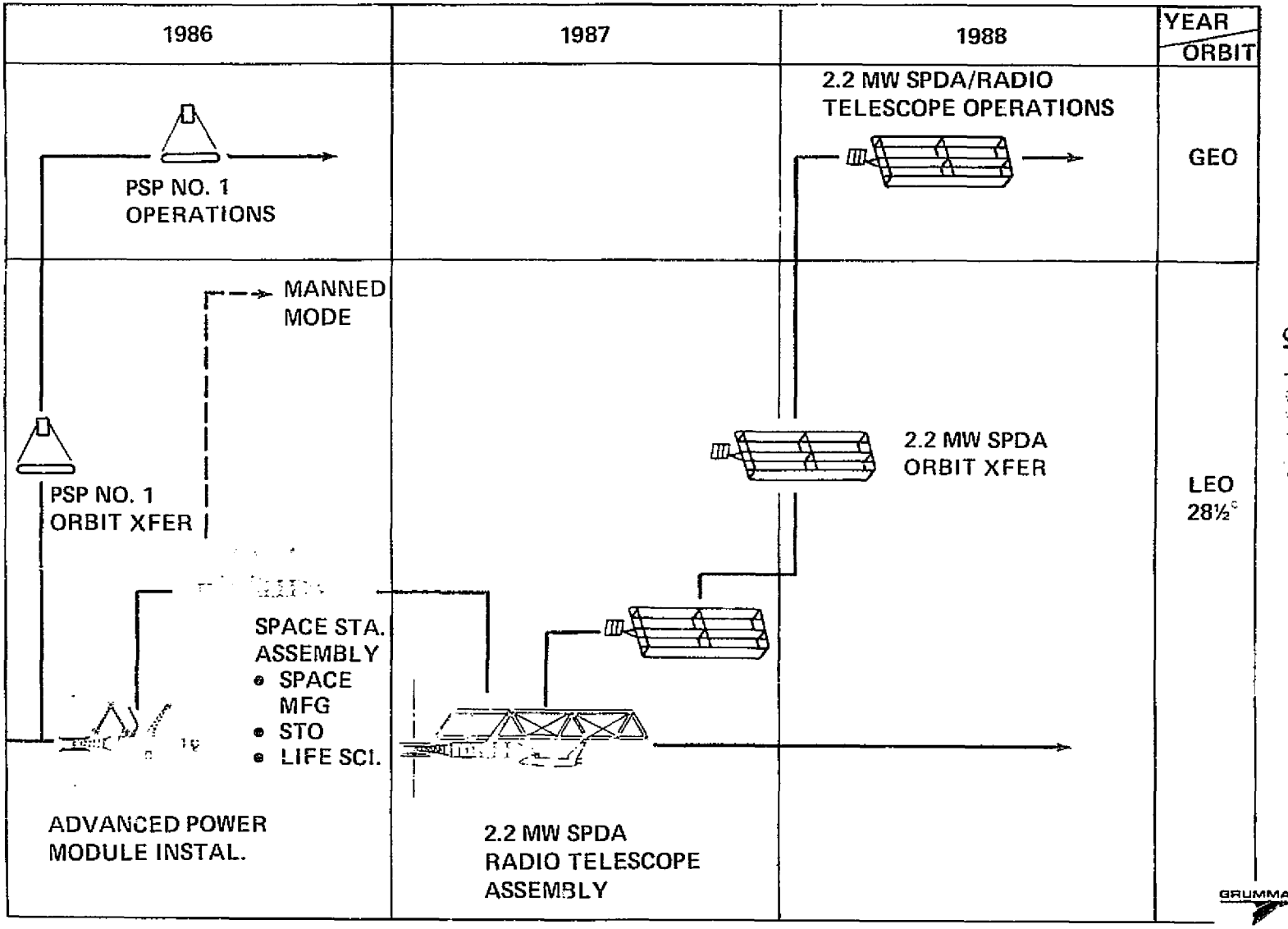
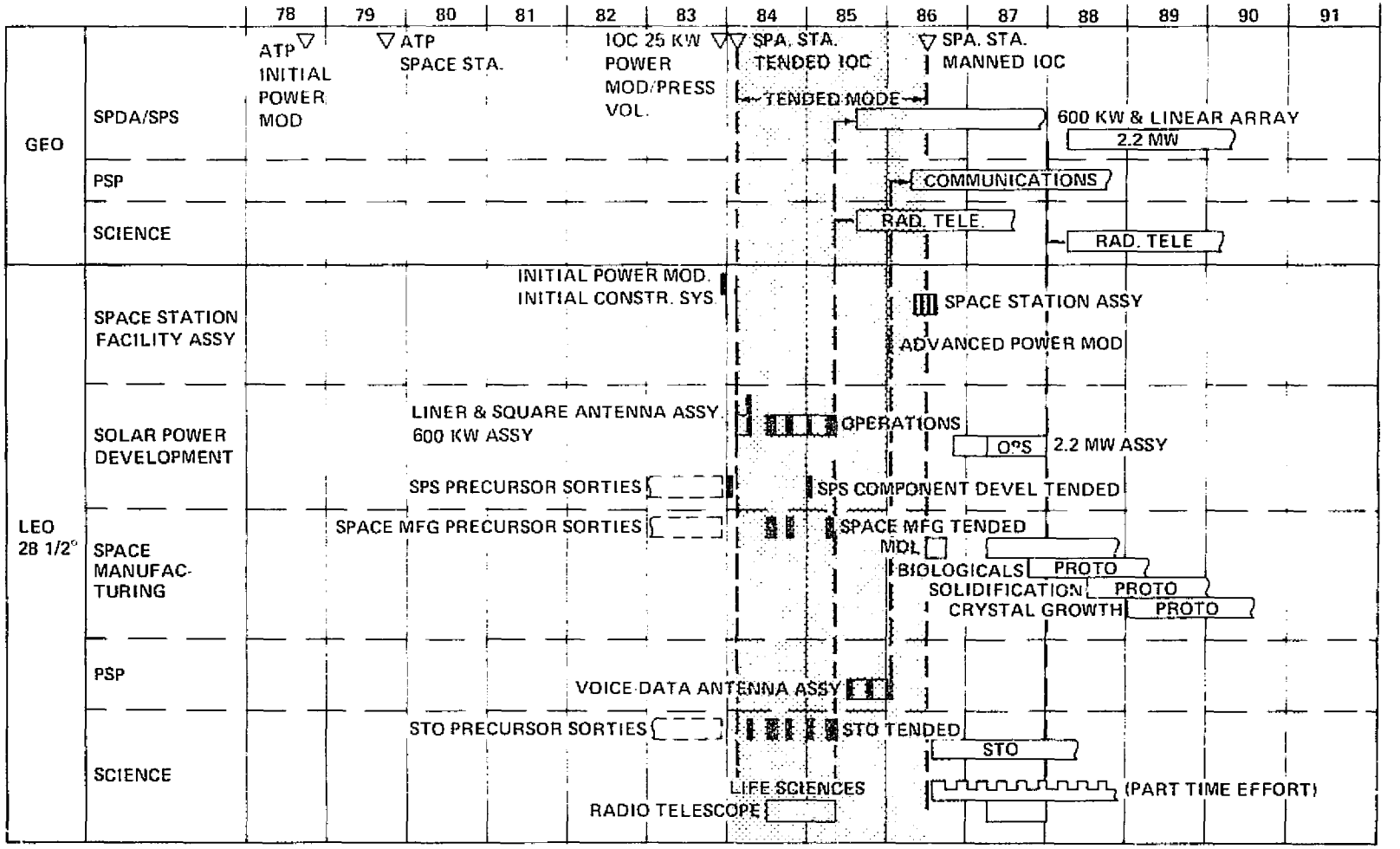
G414(1/2)

OPTION – TENDED MODE/MANNED MODE – SPACE STATION SYSTEM PROGRAM (CONT'D)



G-414(2/2)

OPTION–TENDED MODE/MANNED MODE–SPACE STATION SYSTEM PROGRAM SCHEDULE



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G-410

SPACE STATION SYSTEM PROGRAM FLIGHT SEQUENCE

FLT NO.	CONSTR CREW STS	CONSTR CREW S.S.	STS PAYLOAD MAJOR ITEMS	SHUTTLE DAYS ON ORBIT	
1	4		• INITIAL POWER MOD – SOLAR ARRAY – S & C – MODULE	1	
2&3	2-4 3-4		• EXT TANK • FAB MODULE • CHERRY PICKER • 600 KW SPDA – BLANKETS – AMPLITRONS	2-35 3-30	
4, 5 6 & 7	4-4 5-4 6-4 7-4		• SP MFG EXP • STO EXPERIMENTS • LIFE SCI EXP	4-50 5-30 6-30 7-50	
8, 9 10	8-4 9-4 10-4		• PSP STR MATL • PSP ELECTRONICS	8-30 9-30 10-30	
11, 12, 13, 14, 15, 16, 17	11-4 12-4 13-4 14-4	 15-4 16-7 17-7	ADV PWR MODULE LABS 1 & 2 AIR LOCK & LOG MOD S/S & HAB MOD HAB MODS 2.2 MW SPDA MATL 2.2 MW SPDA EQUIP	11-2 12-2 13-2 14-2 15-2 16-2 17-2	
18, 19 20		18-8 19-7 20-8	RESUPPLY-RCS, EXPEND RESUPPLY-RCS, EXPEND SP MFG BIO BRANCH MOD	18-2 19-2 20-2	

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K-418

SHUTTLE PAYLOAD DATA

FLT NO.	WGT Kg X 10^3	VOL M^3
1	12	154
2&3	2-26 3-13	2-235 3-237
4, 5 6 & 7	4-17 5-21 6-16 7-18	4-186 5-186 6-184 7-188
8, 9 10	8-14 9-15 10-24	9-235 9-237 10-235
11, 12, 13, 14 15 16 17	11-13 12-24 13-24 14-24 15-26 16-11 17-11	11-234 12-232 13-232 14-232 14-232 16-177 17-177
18 19	18-4 19-4	18-2 19-2
20	20-7	20-2

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SPACE TIME CONSTRAINTS DATA
SPACE STATION SYSTEM PROGRAM FLEXIBILITY

PROGRAM ELEMENT	DEVELOPMENT PERIOD*–YRS
SPACE STATION	
POWER MODULE (INITIAL)	3
POWER MODULE (ADVANCED)	4
CONSTRUCTION SYSTEM	3½
SPACE STATION MODULES (NEW)	4½
SPACE STATION LABS.	2
TRANSPORTATION SYSTEM	
OTV–P/C	5
HLLV–CLASS 4	8
OTV–C	4
MISSION HARDWARE	
SOLAR POWER SPDA	3
SPACE MFG PROCESS	3
PSP (COMM. ANT.)	3½
STO (LESS INST.)	4

*PHASE C/D GO-AHEAD TO SPACE DEPLOYMENT/FAB.

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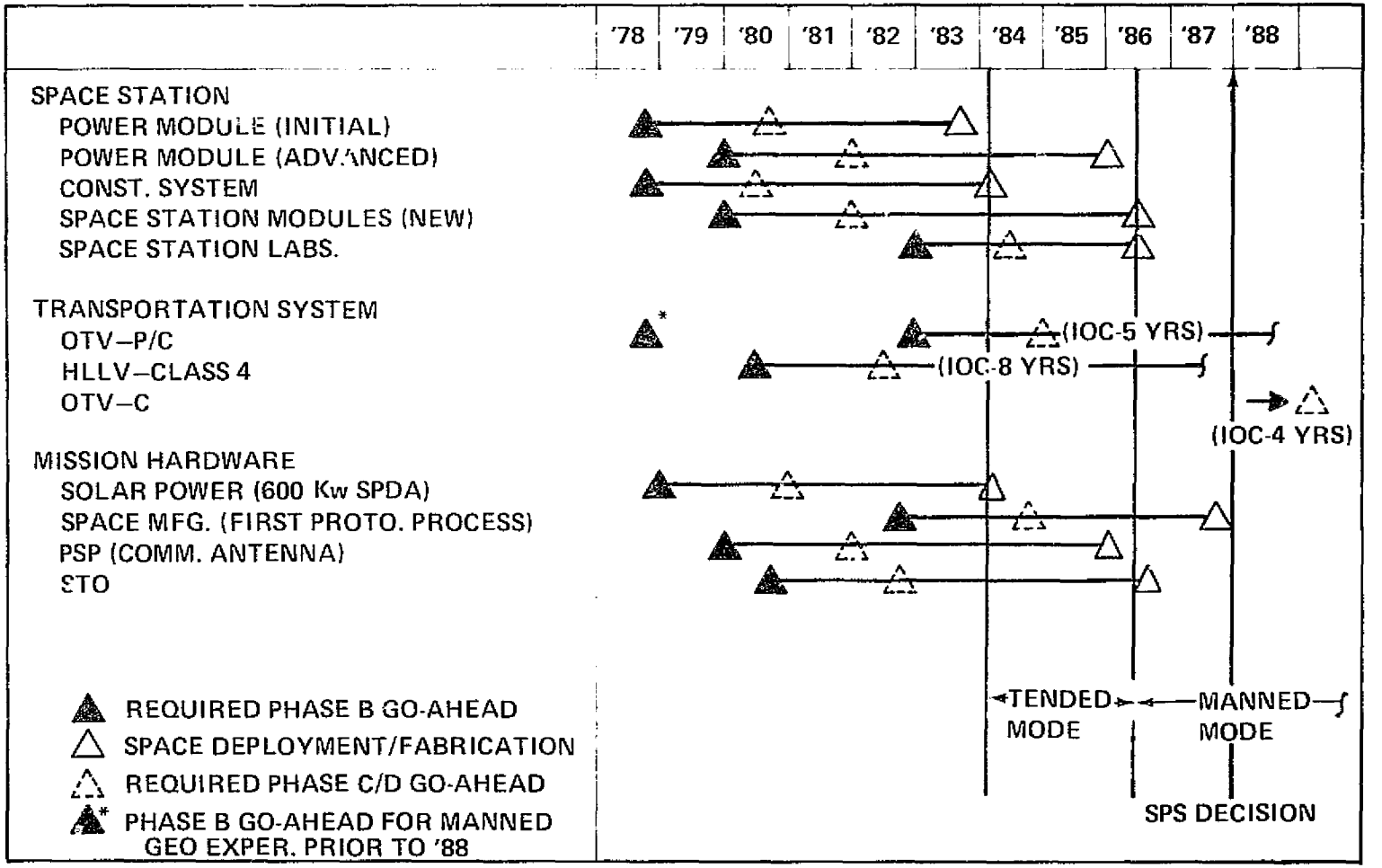
LEAD TIME REQ'MTS SCHEDULE
SPACE STATION SYSTEM PROGRAM – TENDED & MANNED MODES



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K-414

EXTENDED ORBITER FLIGHT DURATION
PENALTIES AND ON-ORBIT ALLEVIATION METHODS

		LAUNCH WT. PENALTY (Kg)				ALLEVIATION METHOD (TENDED PHASE)
		30 DAYS		90 DAYS		
		4 MEN	7 MEN	4 MEN	7 MEN	
VEHICLE CONSUMABLES	EPS (20 KW AVE CONT)	11,500	11,500	36,400	36,400	• POWER MODULE (INCL RADIATOR)
	RCS	1,570	1,570	5,660	5,660	• GRAV.GRAD., CMG'S • DOCK TO EXT TANK
CREW CONSUMABLES	N_2	612	612	2,000	2,000	—
	LO_2 – Δ REQ'D	240	335	815	1,080	• RLSE
	– AVAIL FROM EPS	406	406	1,245	1,245	
	LiOH	147	310	531	982	
	FOOD	145	290	510	925	—
CREW ACCOMMODATIONS	VOLUME (M^3)	24	42	32	56	• HAB MODULE
	SEATS & RESTRAINTS	–	74	–	74	
	CREW EQUIPMENT	–	44	–	44	
	CREW	–	272	–	272	
	HYGIENE	25	56	90	170	
	RESCUE	–	79	–	79	

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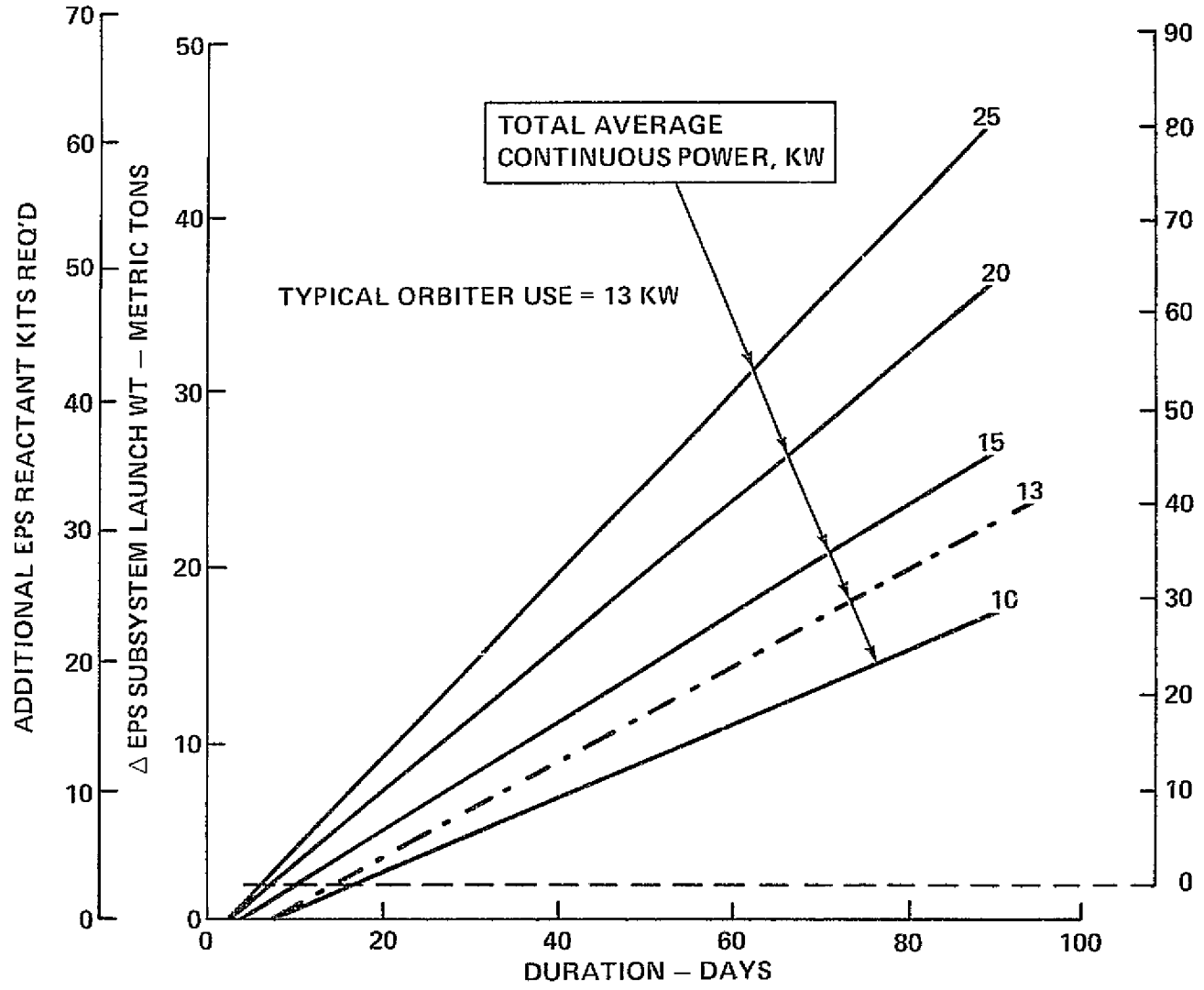
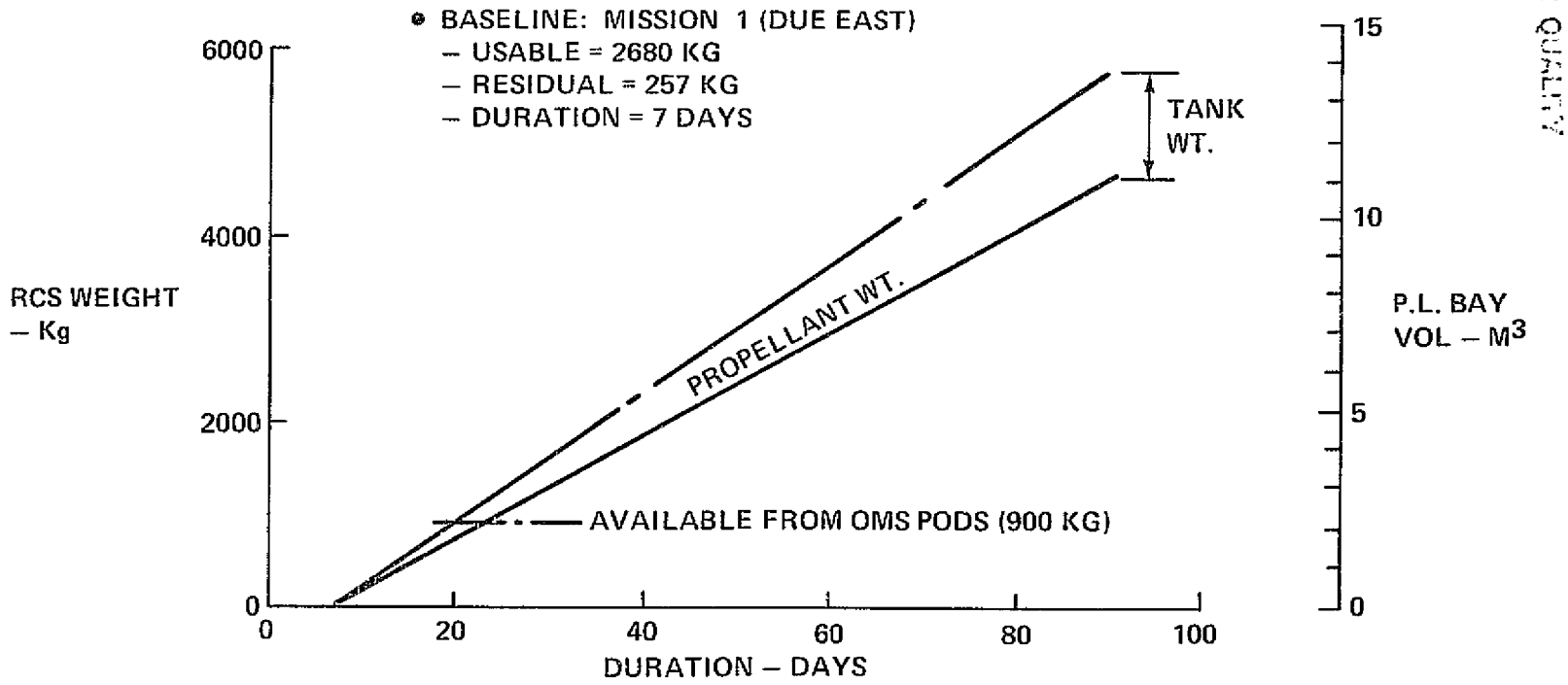
JG-441

EXTENDED DURATION ORBITER
EPS REQ'MTS ABOVE BASELINE (FUEL CELLS)



JG-442

EXTENDED DURATION ORBITER
RCS SYSTEM REQ'TS ABOVE BASELINE



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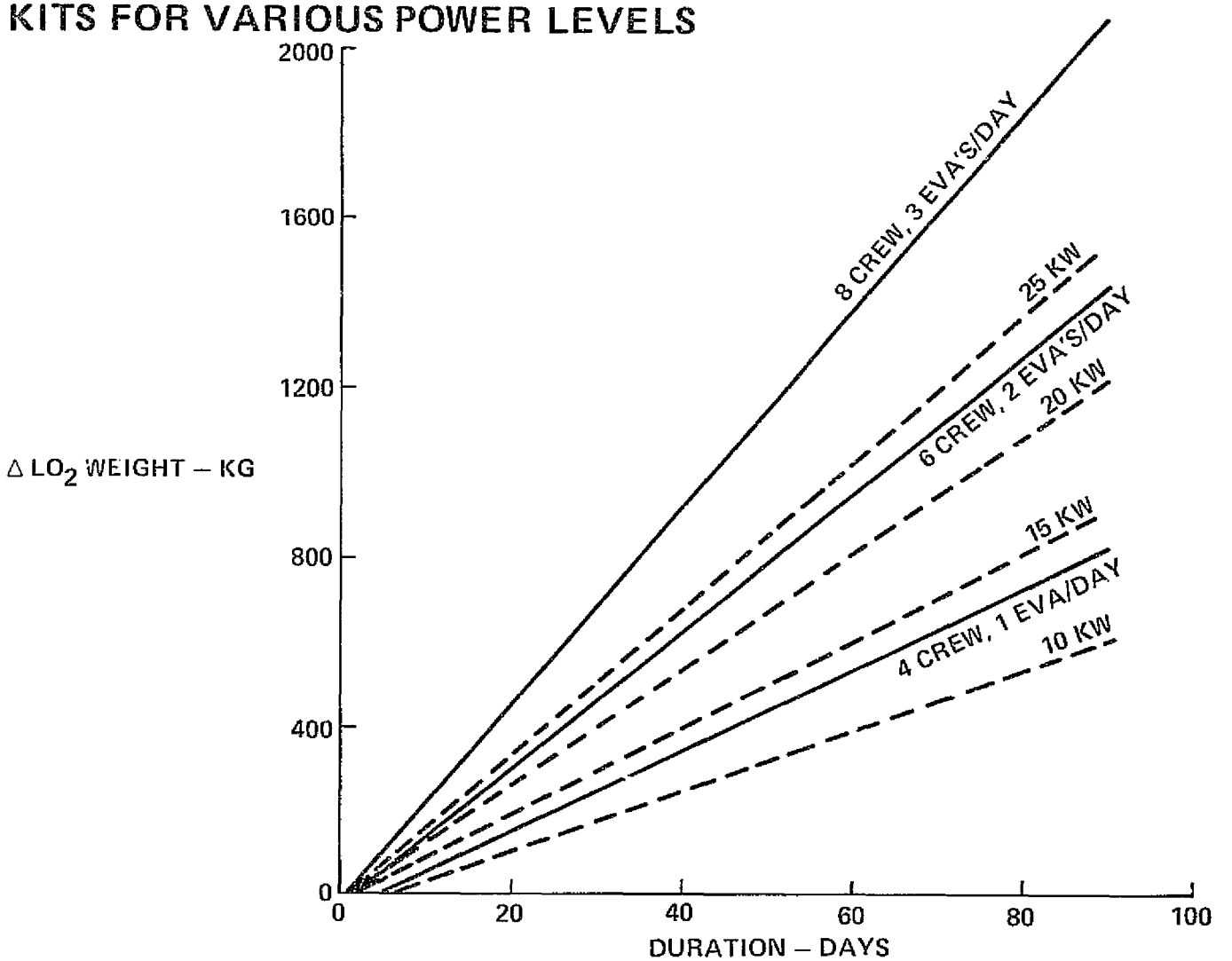
JG-443

EXTENDED DURATION ORBITER

CREW O_2 REQ'TS VS O_2 AVAILABLE FROM EPS KITS FOR VARIOUS POWER LEVELS



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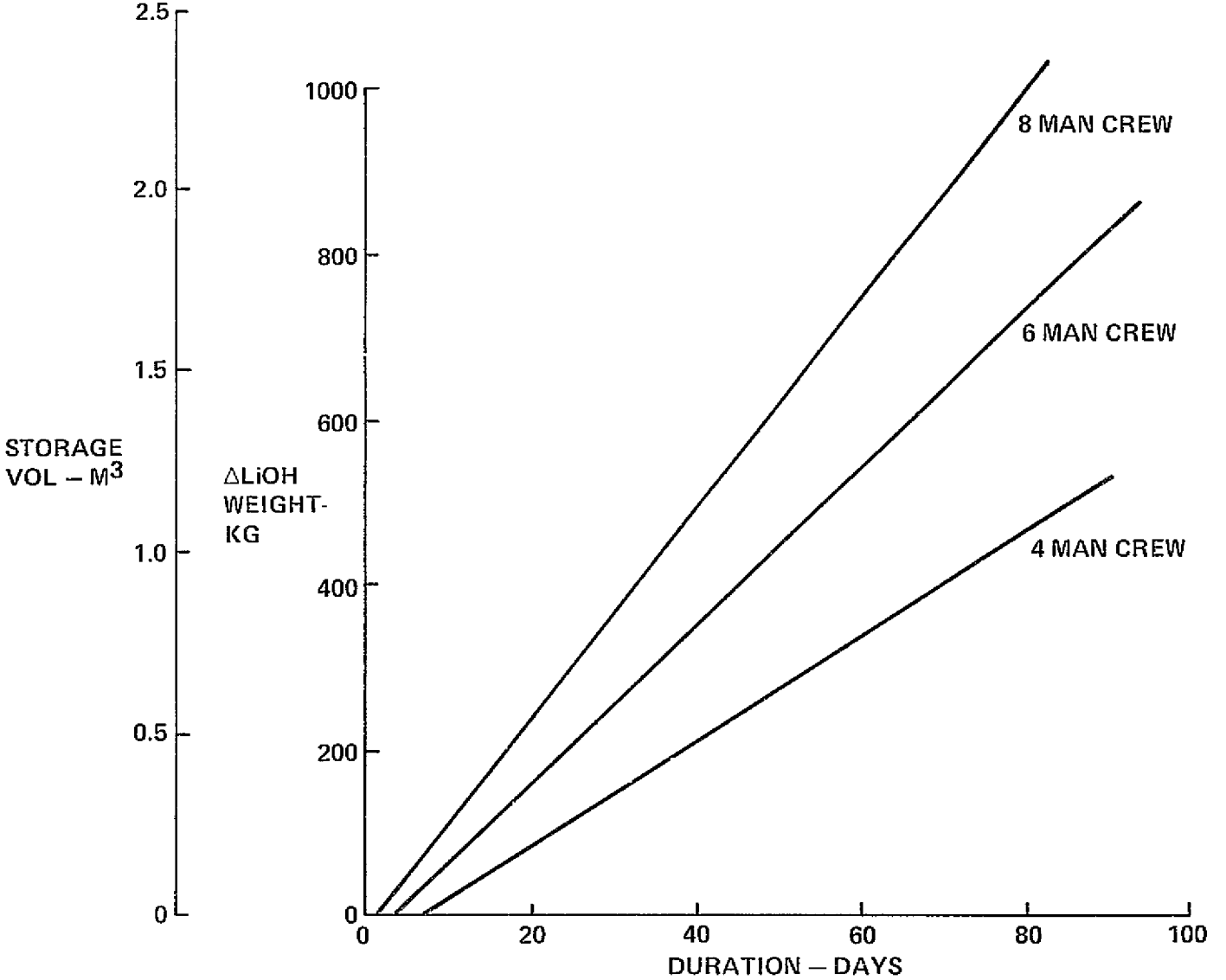
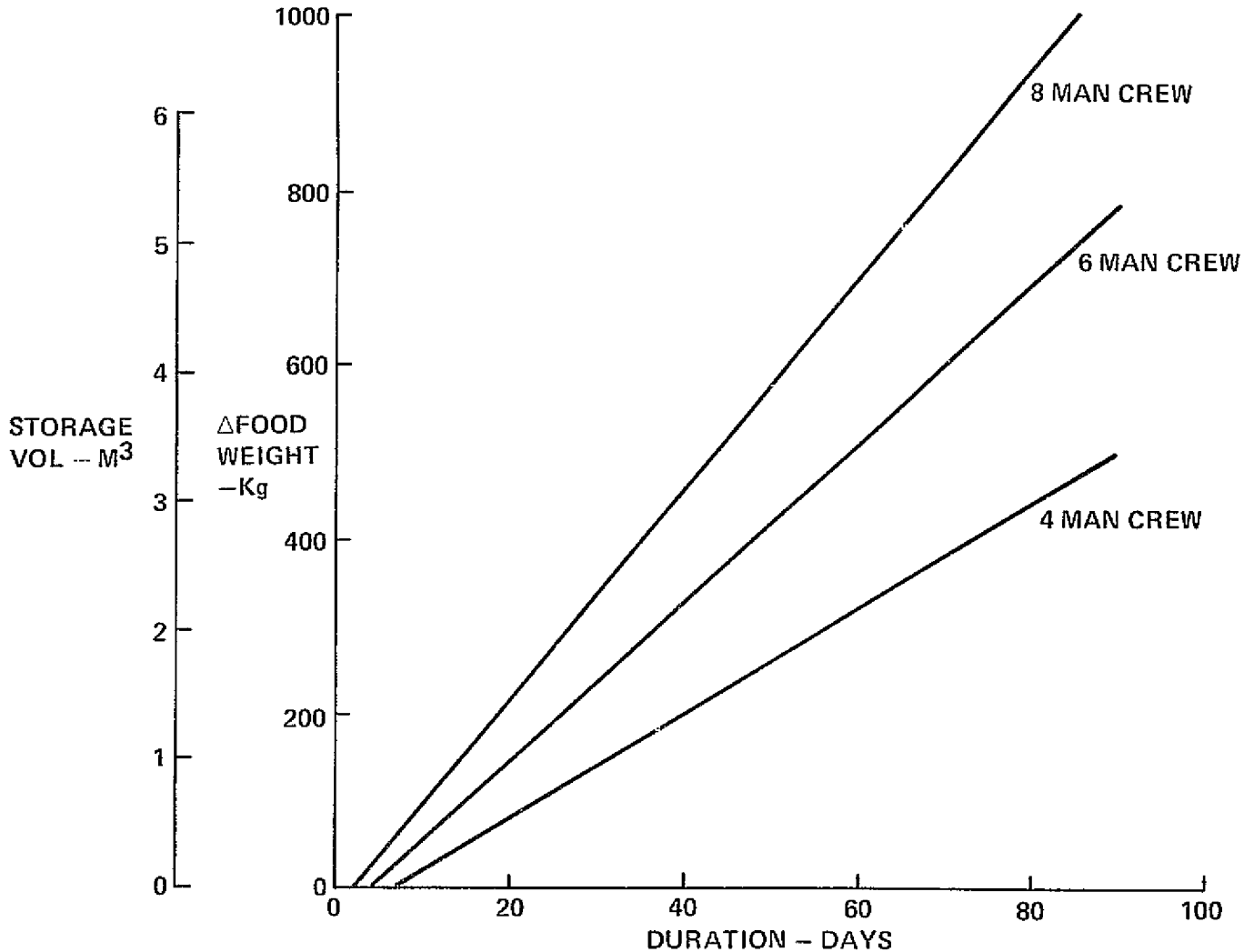
JG-444

EXTENDED DURATION ORBITER
LiOH REQ'TS ABOVE BASELINE



JG-445

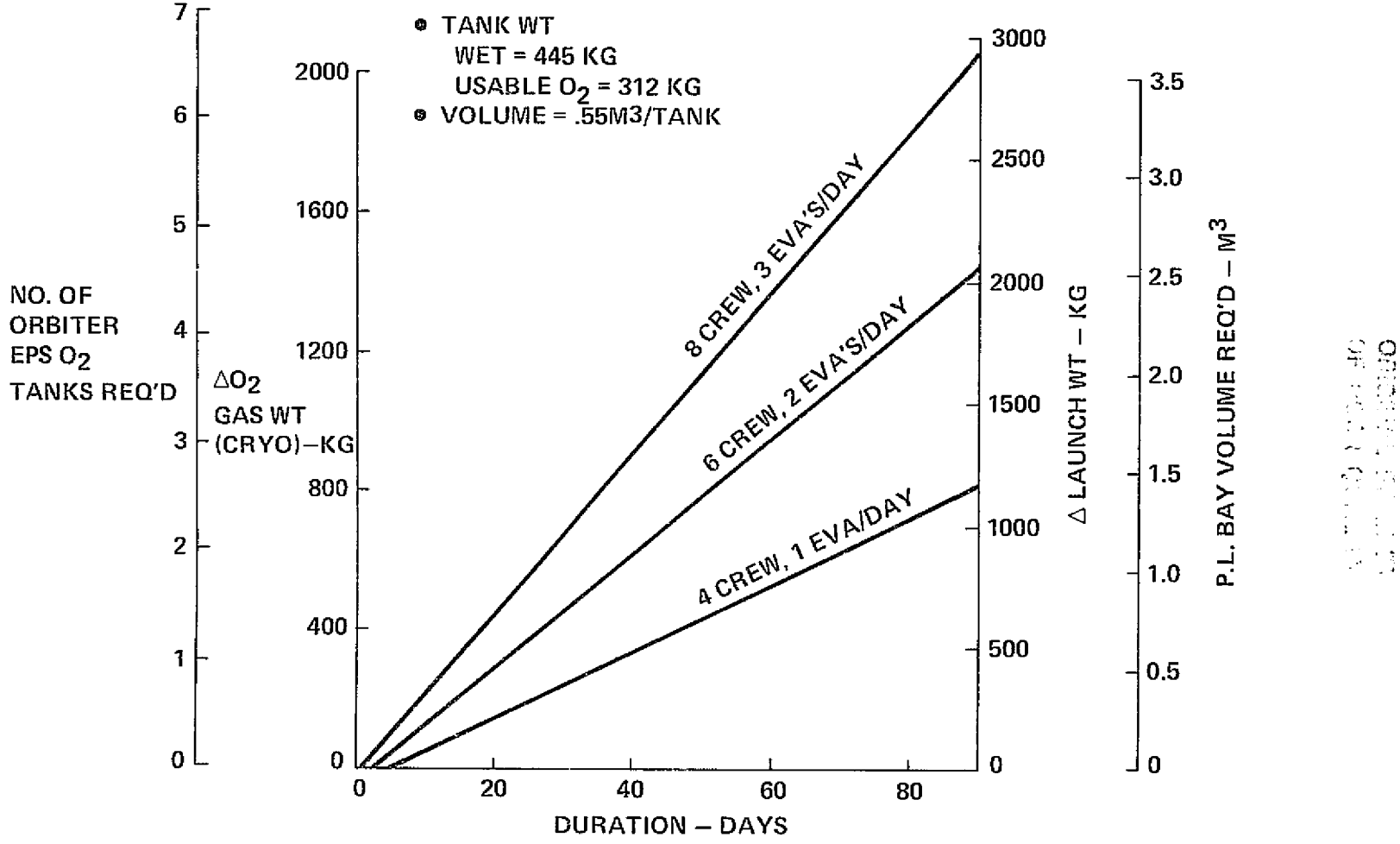
EXTENDED DURATION ORBITER
FOOD REQ'TS ABOVE BASELINE



GRUMMAN

JG-446

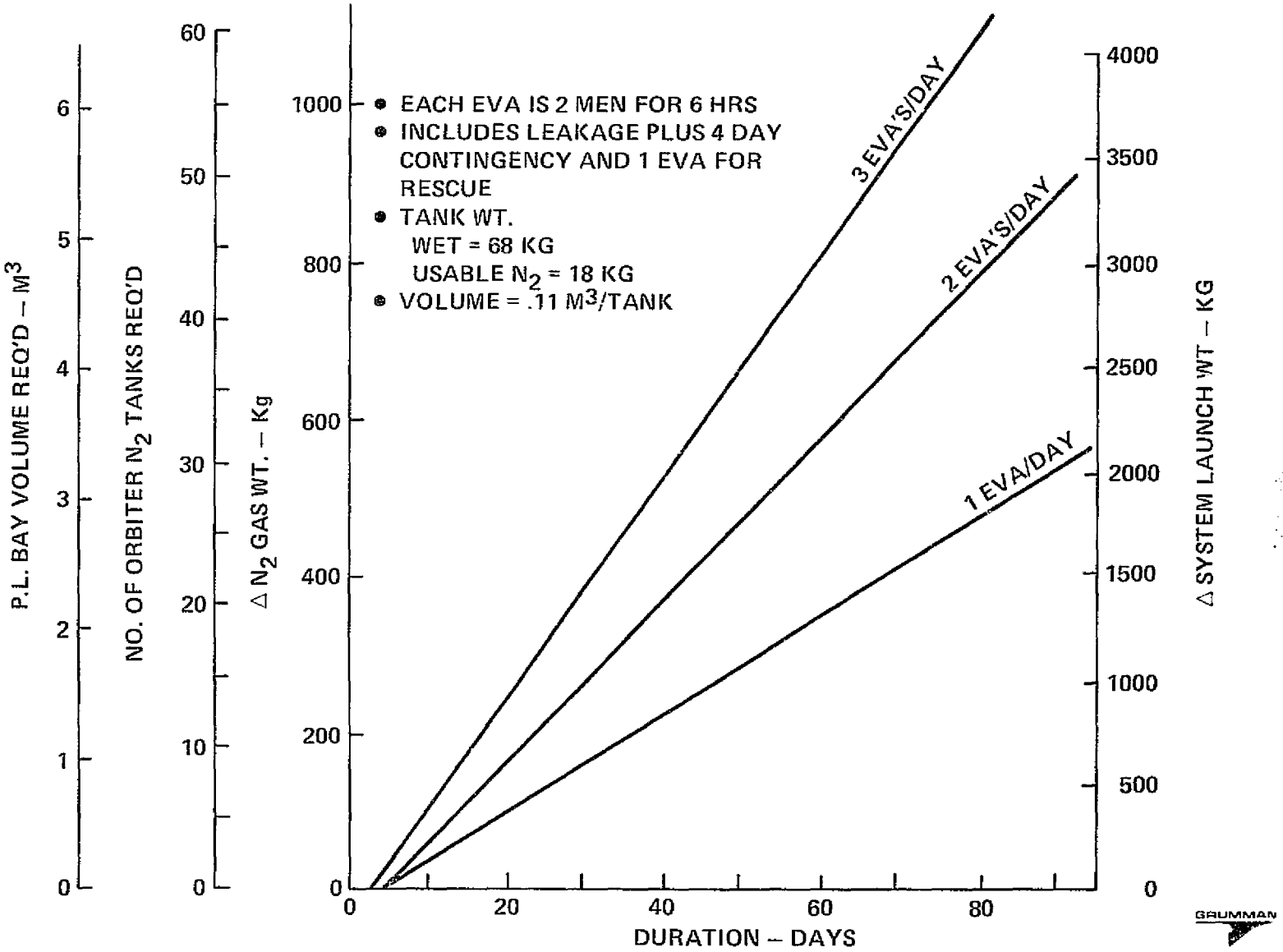
EXTENDED DURATION ORBITER
CREW O_2 REQ'TS USING EPS O_2 TANKS FOR STORAGE



GRUMMAN

JG-447

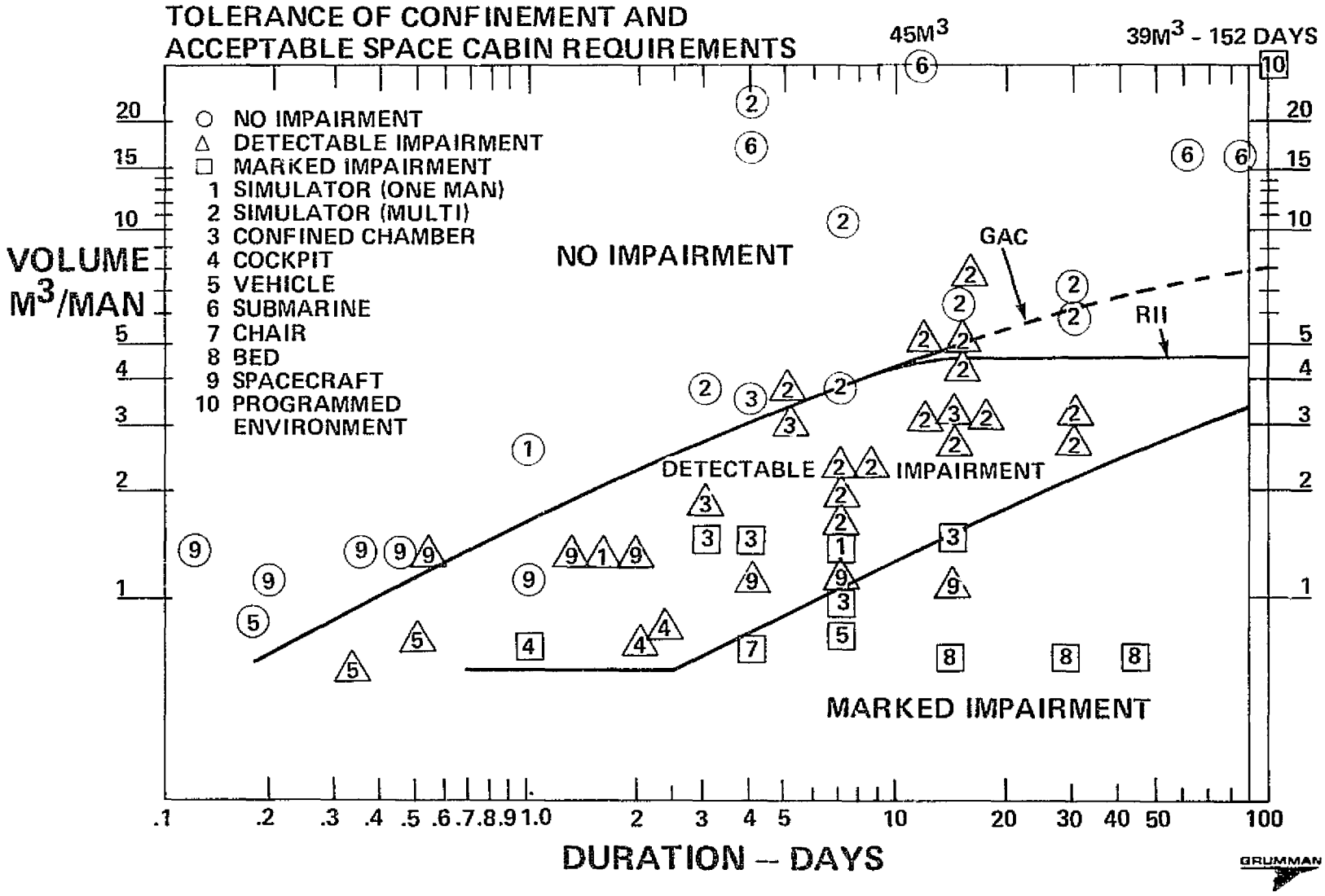
EXTENDED DURATION ORBITER
N_2 REQ'TS USING ADDITIONAL ORBITER N_2 TANKS FOR STORAGE



GRUMMAN

JG-448

FREE VOLUME – DURATION TOLERANCE FACTORS IN CONFINEMENT



JG-449

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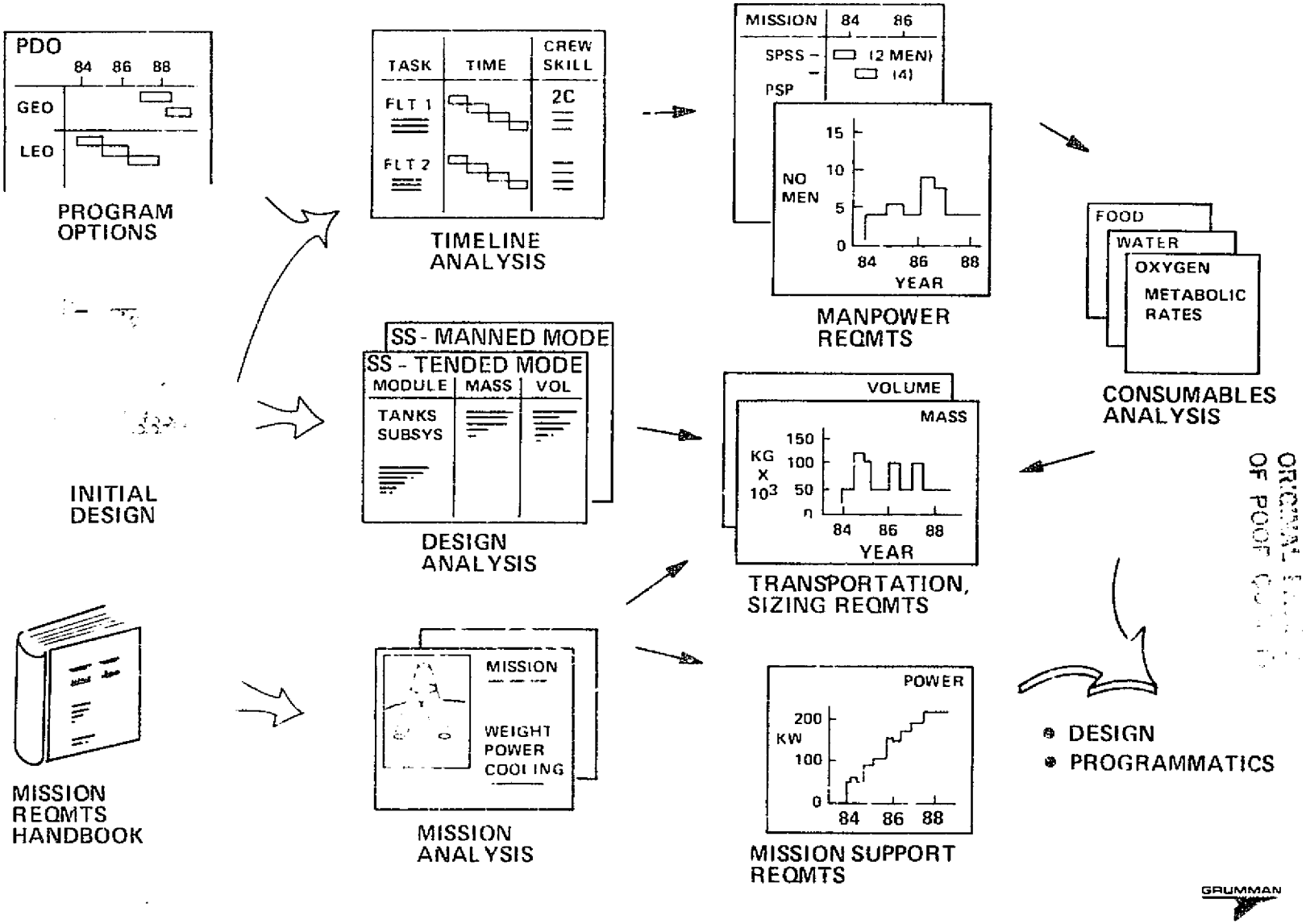
INTEGRATED SPACE STATION SYSTEM REQUIREMENT DEVELOPMENT



G-412

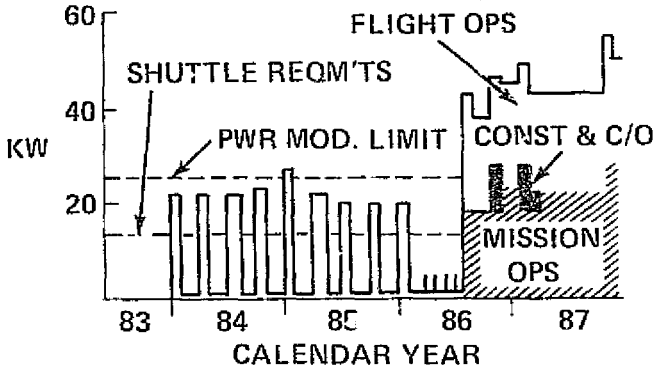
SPACE STATION SYSTEM
INTEGRATED REQUIREMENTS GROUNDRULES

- ONE SHUTTLE FLIGHT PER MONTH DURING SPACE STATION ASSY
- ONE SHUTTLE FLIGHT PER QUARTER DURING CONSTRUCTION AND MISSION OPERATIONS
- SHUTTLE PROVIDES MANNED AND LOGISTICS SUPPORT DURING TENDED MODE
- SINGLE SHIFT CREW/10 HOUR MAX WORKDAY
- SIX HOUR EVA DAILY MAXIMUM/PERSON
- SPACE STATION PROVIDES S&C DURING TENDED OPERATIONS
- SPACE STATION PROVIDES 13KW CONT. POWER TO SHUTTLE DURING TENDED OPERATION
- SPACE MFG. OPERATIONS ARE INACTIVE DURING CONSTRUCTION TASKS

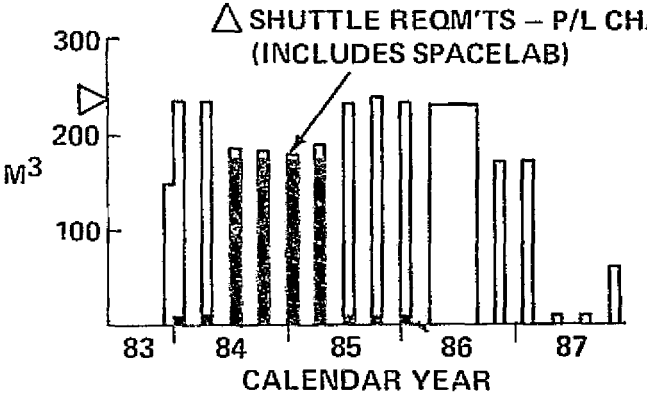
INTEGRATED SPACE STATION REQUIREMENTS IN ORBIT BY MONTH

TENDED MODE/MANNED MODE OPTION

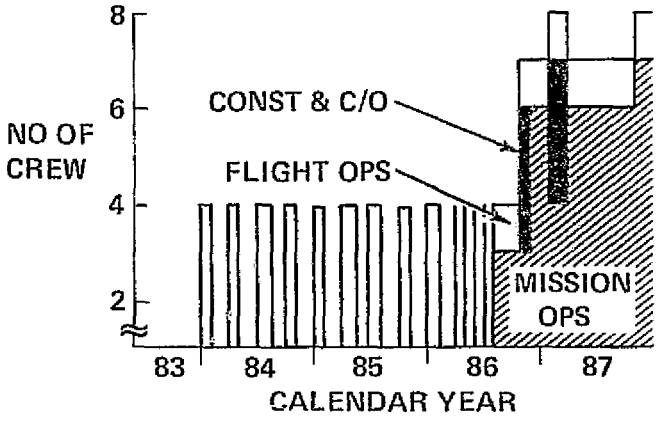
ELECTRICAL POWER



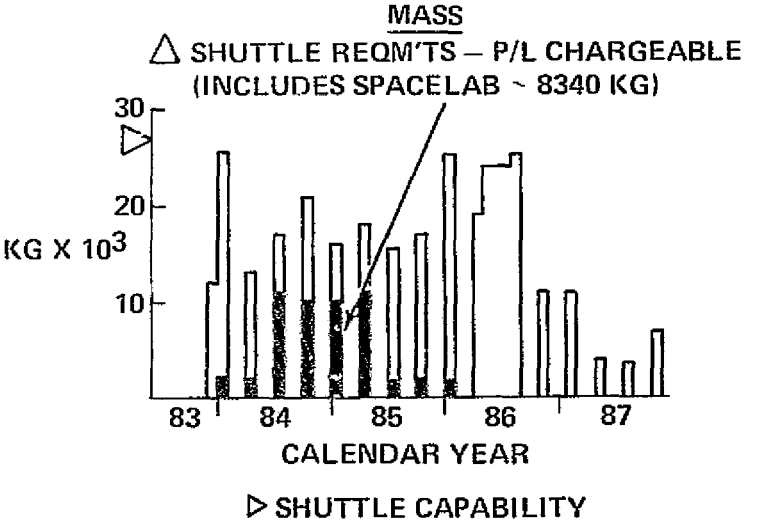
VOLUME



NO. OF CREW



MASS



▷ SHUTTLE CAPABILITY

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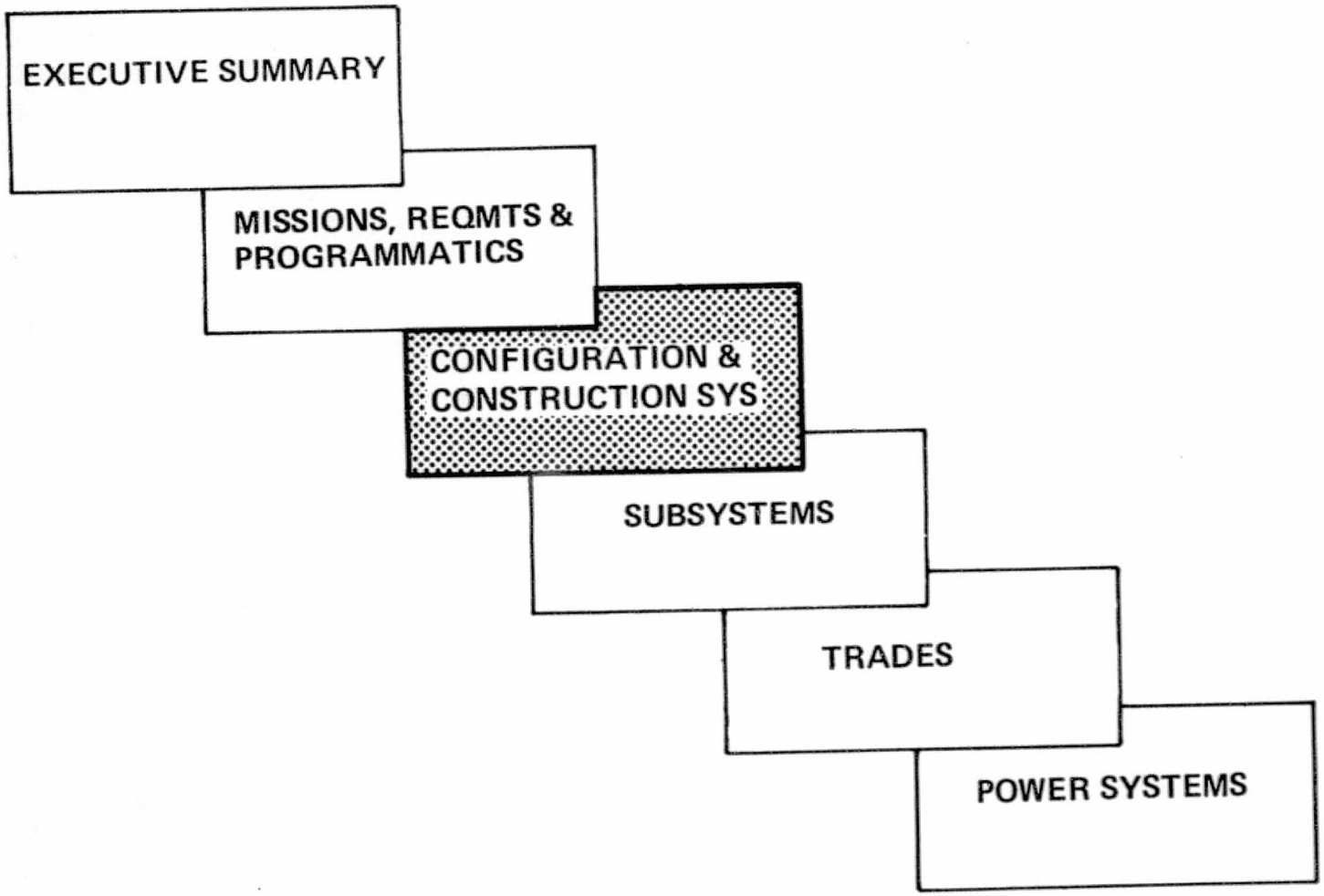
GRUMMAN

G-413

AGENDA SPACE STATION PROGRAM REVIEW MEETING
19 APRIL 1977



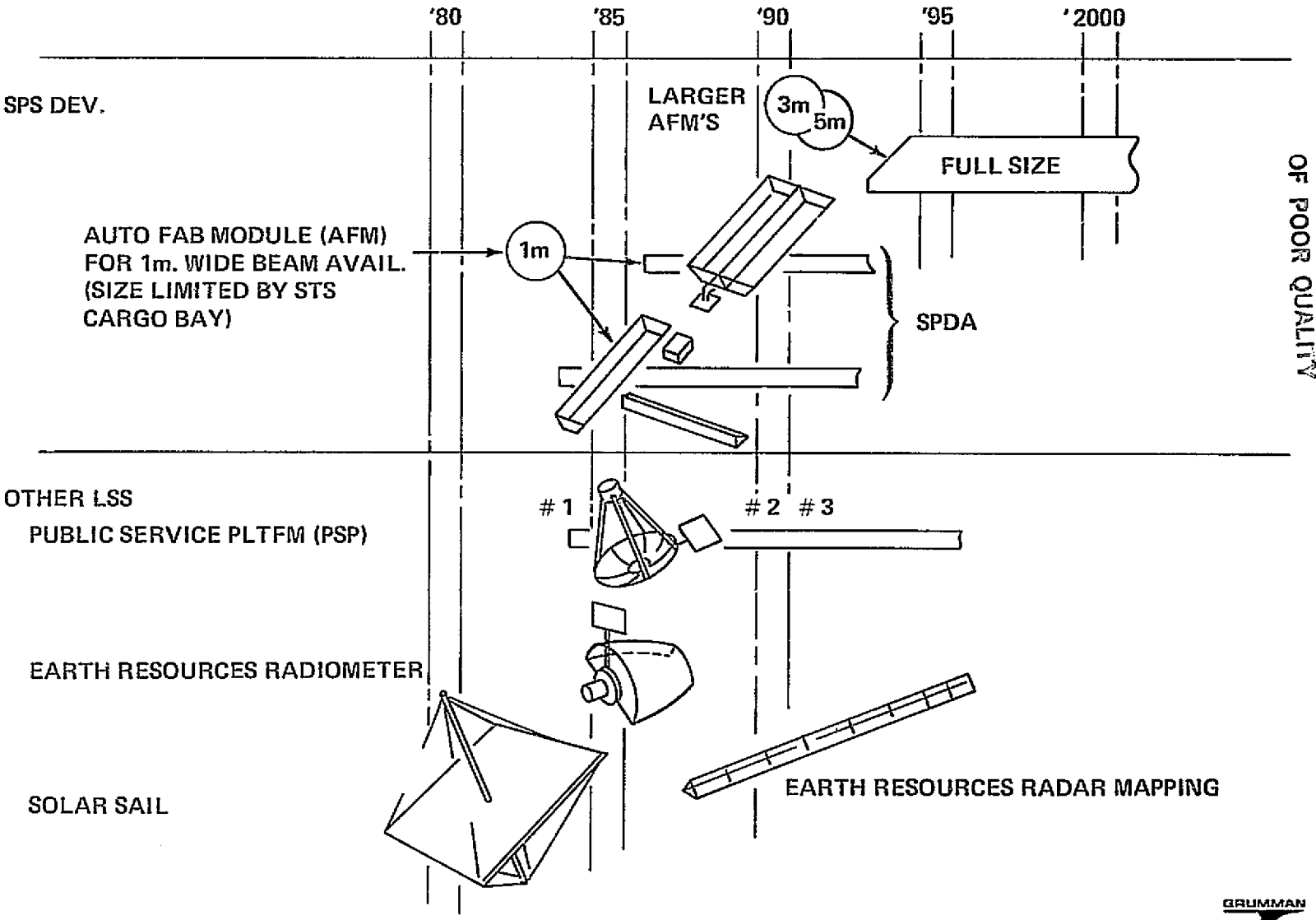
GRUMMAN

CONSTRUCTION SYSTEM GENERIC ISSUES

- REQUIREMENT
  - DEFINITION OF LARGE SPACE STRUCTURES IN MID '80s
- CONCEPT
  - WRAPAROUND VS "HYBRID" VS "EXTRUSION"
  - DEGREE OF AUTOMATION
  - ORBIT(S)
- CONFIGURATION
  - WORK BENCH:
    - HOW BIG - STRONG – STIFF
    - PERMISSIBLE THERMAL DISTORTION
    - EXT. TANK VS ERECTOR SET VS AFM BEAM RAFT
  - CRANE/CHERRY PICKER:
    - FIXED BASE VS TRAVELLER (RAIL: RAIL ON BOOM: WALKER)
    - REACH - STIFFNESS – SPEED
    - AUTOMATED VS MANNED
    - HOW MANY

GRUMMAN

TWO CATEGORIES OF LARGE SPACE STRUCTURE (LSS)



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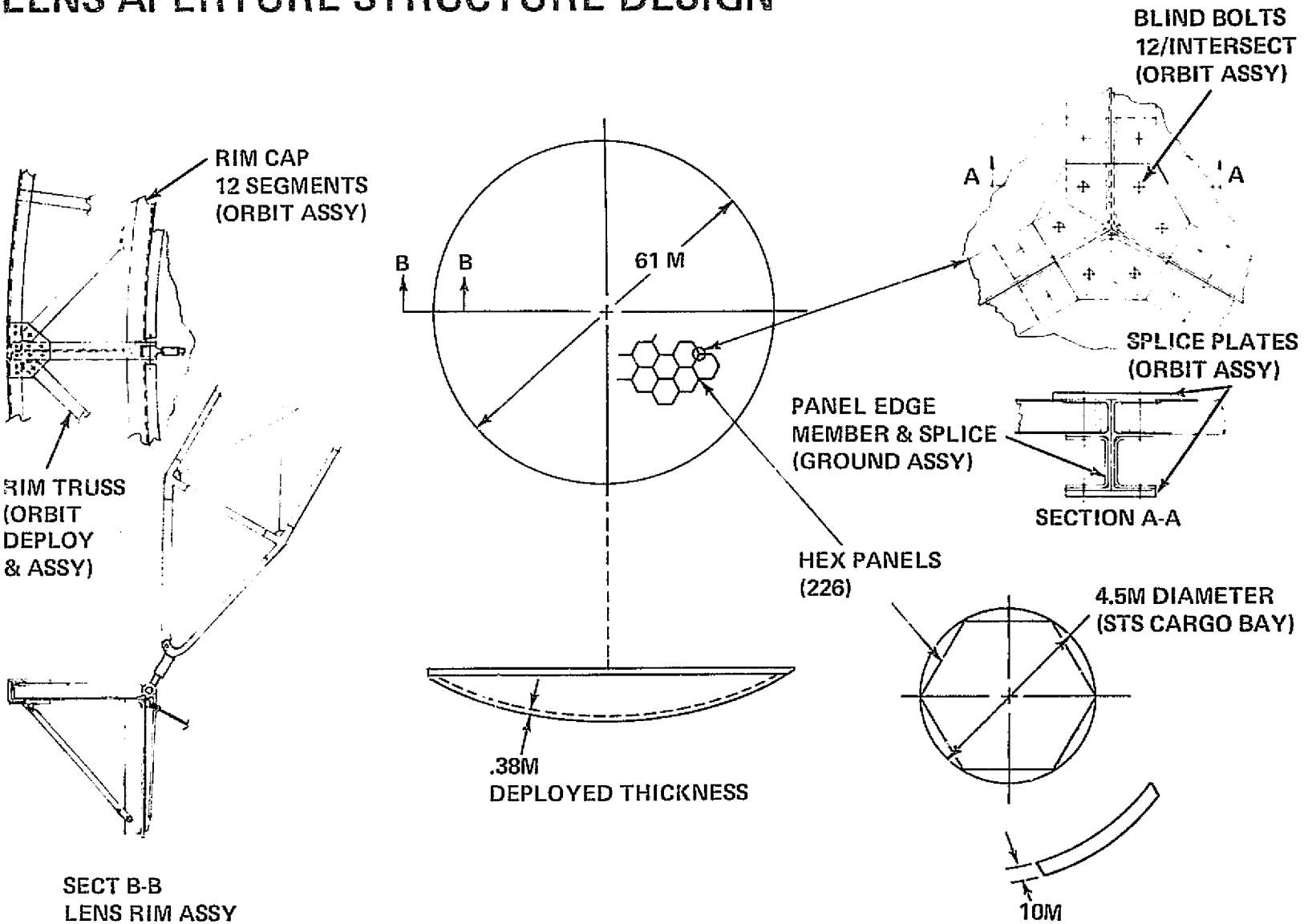
GRUMMAN

JG-437

LENS APERTURE STRUCTURE DESIGN



GRUMMAN

JG-416

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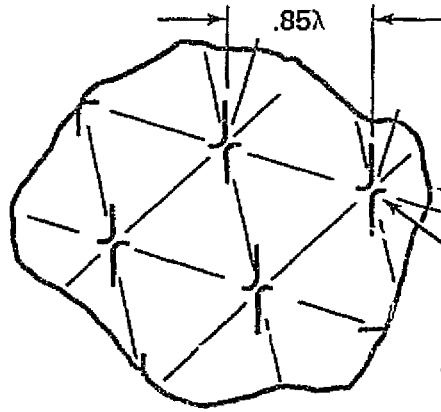
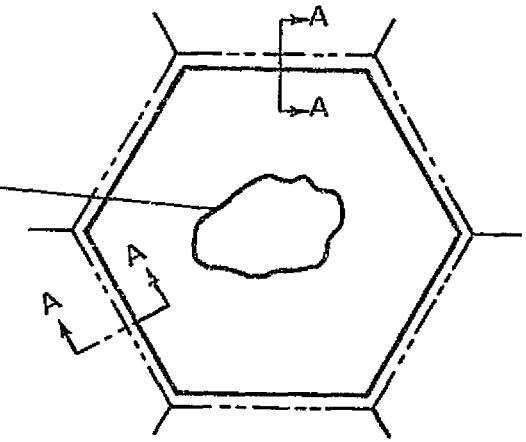
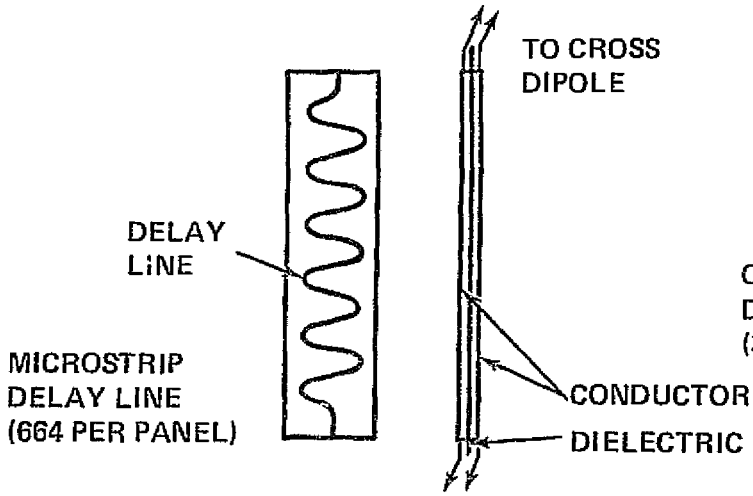
LENS BOOTLACE ELEMENT DESIGN



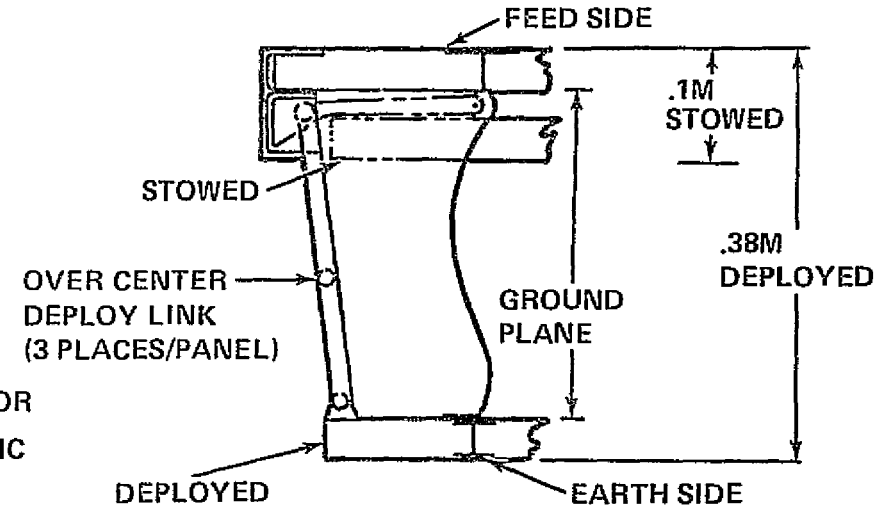
DETAIL OF
ANTENNA ELEMENTS



TYPICAL LENS PANEL



DETAIL OF DELAY LINE ELEMENT



SECT A-A

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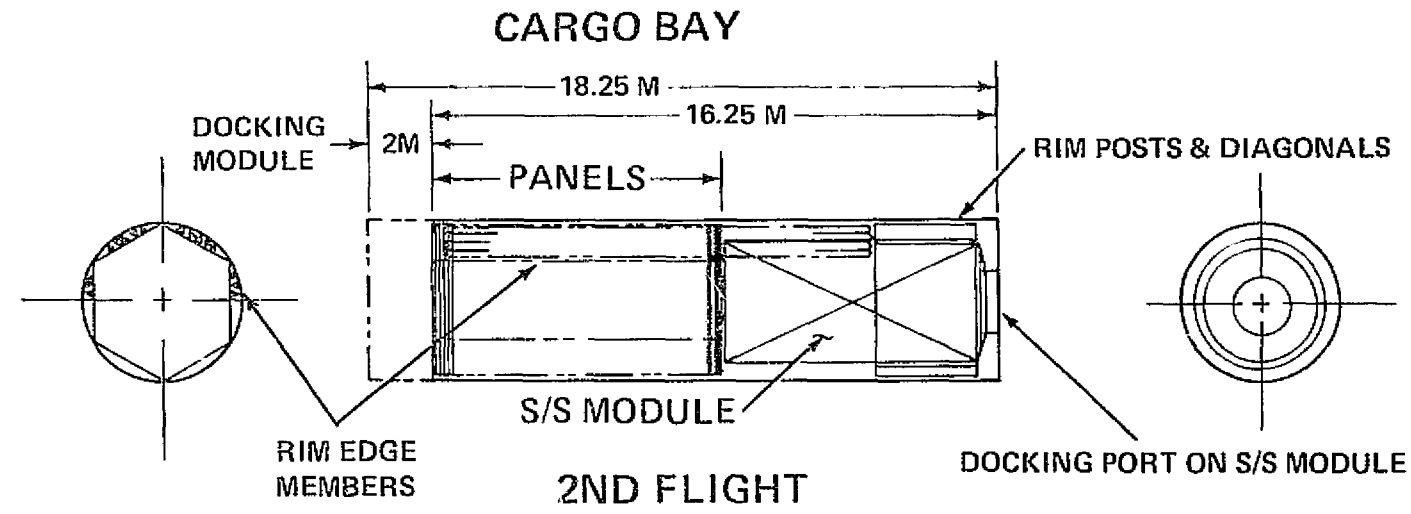
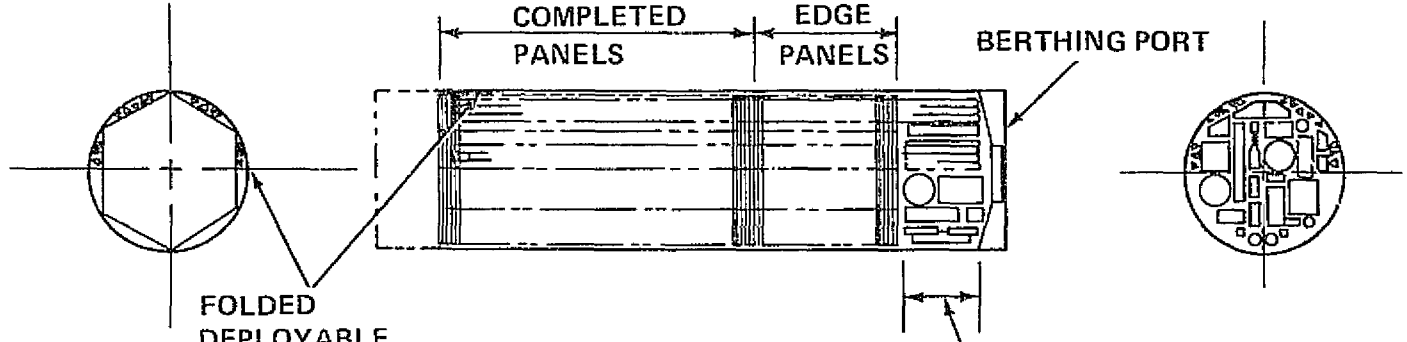
GRUMMAN

JG-413

PSP ANTENNA SHUTTLE PACKING CONCEPT





- SOLAR ARRAY COMPONENTS
- PANEL CONNECTNG PLATES
- RIM & PANEL FASTENERS
- ATTITUDE CONTROL COMPONENTS
- RIM/STRUT FITTINGS
- ELECT & STRUCT CABLES

GRUMMAN

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JG-423

PSP ANTENNA CONFIGURATION DATA

	WEIGHT (KG)	WHERE FABRICATED	STS CAPACITY REQ'D
ANTENNA APERTURE	(17,218)		
• LENS PANELS	15,568	GROUND	1.2
• APERTURE RIM	1,650	GROUND	0.1
FEED SUPPORT STRUCTURE	1,500	GROUND	0.1
SUBSYSTEM MODULE	(2,643)	GROUND	0.4
• STRUCTURE	100		
• FEED/DIPLEXER ASSEMBLY	125		
• COMMUNICATIONS ELECTRONICS	450		
• TT&C	30		
• FLIGHT CONTROL	118		
• PROPULSION	70		
• THERMAL CONTROL	50		
• ELECTRICAL POWER & INTEGRATION	1,700		
SOLAR ARRAY	600	GROUND	0.2
DRY WT W/O CONTINGENCY	21,961		
25% CONTINGENCY	5,490		
DRY WT. WITH CONTINGENCY	27,451		
PROPELLANT	280		
TOTAL	27,731		2.0

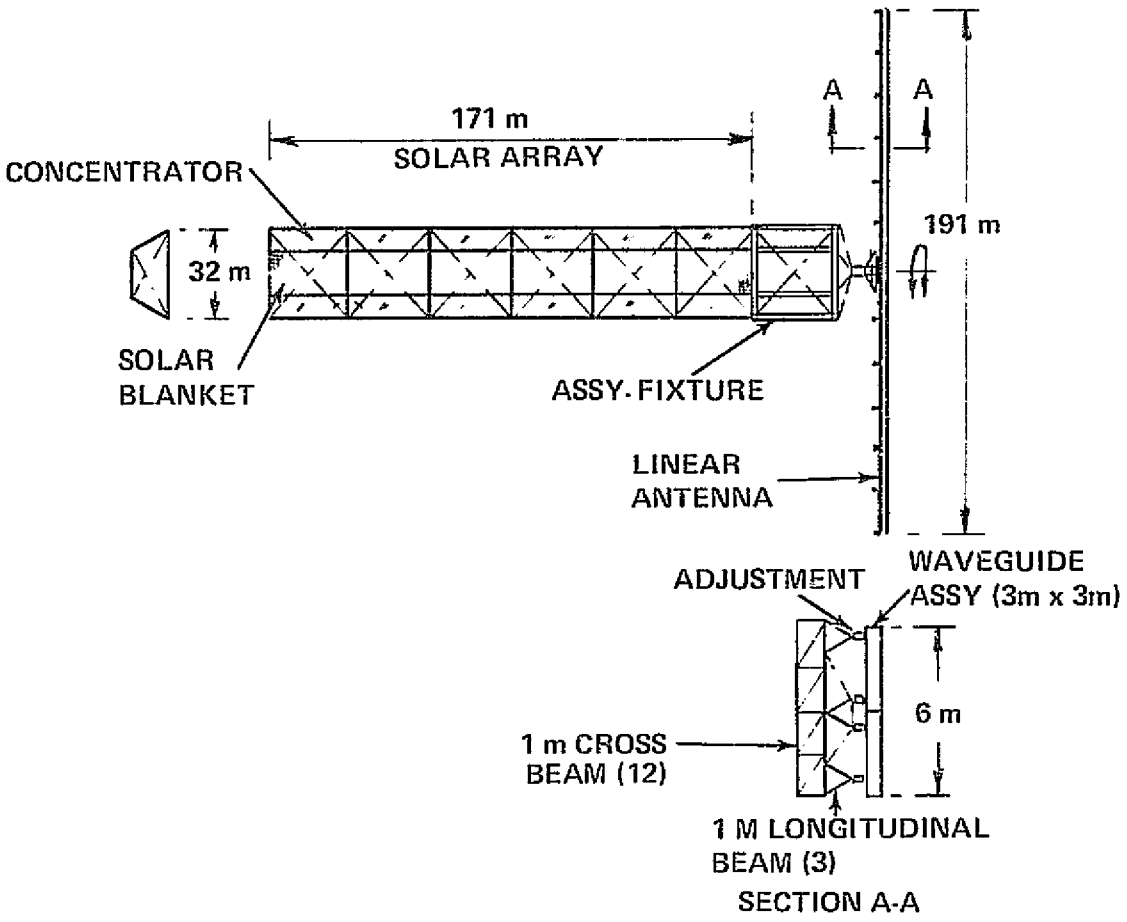
STRUCTURAL DATA:

- LOAD IN FEED SUPPORT STRUCTURE LEG = 174000 N ULT. COMP.
  IUS LAUNCH TO GEOSTATIONARY ORBIT = 1.7 g's LIMIT ACCELERATION
- TEMPERATURE RANGE: 0°C TO -160°C

GRUMMAN

JG-417

600 Mw SPDA CONFIGURATION



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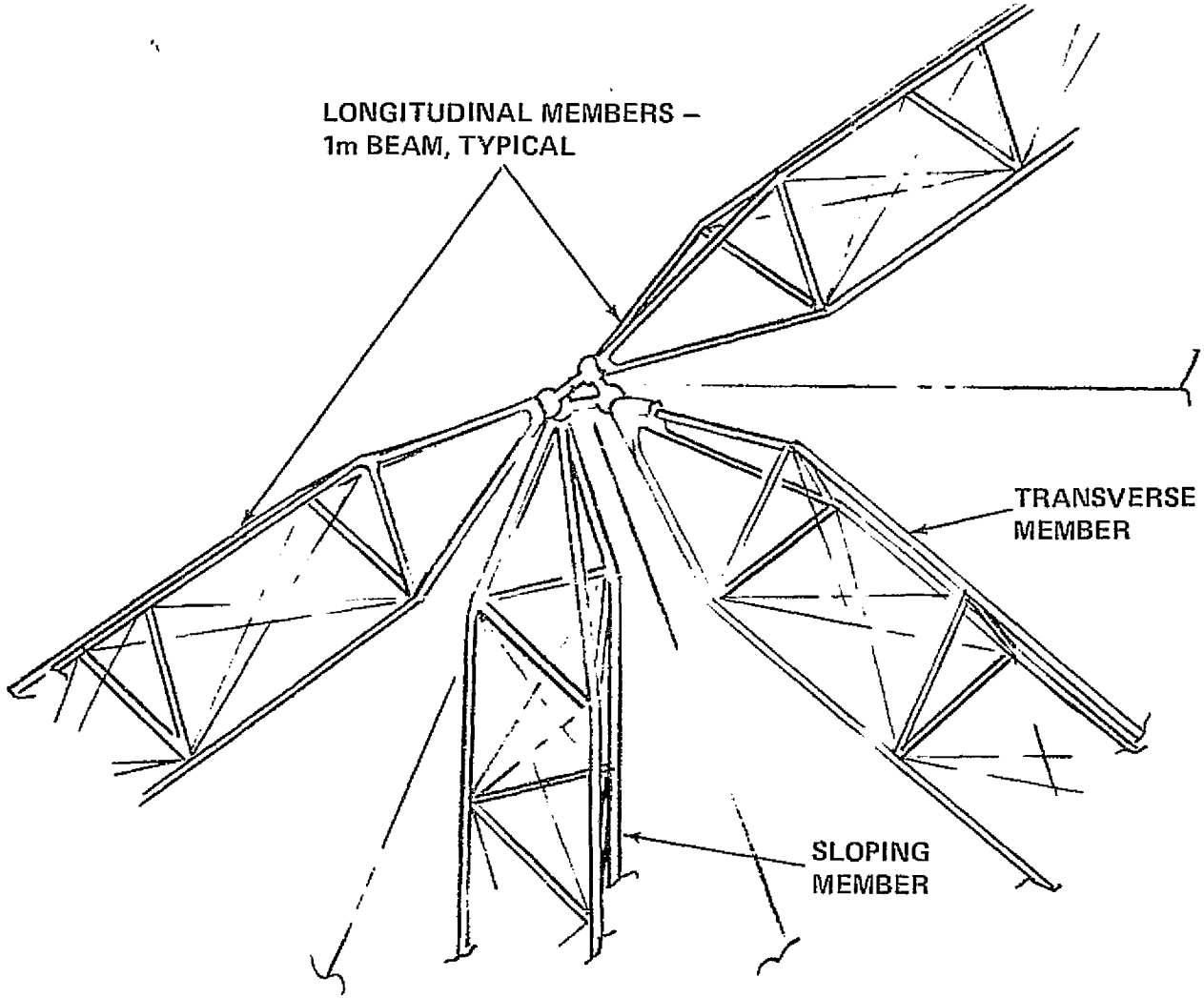
GRUMMAN

JG-453

SPDA – STRUCTURAL JOINT TYPICAL FOR EACH BEAM INTERSECTION



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GRUMMAN

JG-455

600 Kw SPDA CONFIGURATION DATA

ITEM	WT (Kg)	WHERE FAB	STS CAPACITY REQD
SOLAR ARRAY	(3,392)		
STRUCTURE	1,578	SPACE	
SOLAR BLANKET	1,049	GRND	0.02
CONCENTRATORS	80	GRND	
BUSSES & SWITCHES	7	GRND	
CONTINGENCY (25%)	678		
ANTENNA	(10,218)		
STRUCTURE	296	SPACE	
W/GUIDE TUBES	5,317	GRND	1.0
SUPPORT RAILS	347	GRND	
CONTOUR CONTROL	435	GRND	
PWR. DISTRIBUTION	43	GRND	
AMPLITRONS	236	GRND	0.25
PHASE CONTROL ELECT.	1,500	GRND	
CONTINGENCY (25%)			
ROTARY JOINT (INCL 25% CONTIN)	165	GRND	0.23
POWER STORAGE	410	GRND	
STRUCT/DOCKING	300	GRND	
AVIONICS	92	GRND	
RCS	340	GRND	
TOTAL	14,917		1.5

STRUCTURAL DATA:

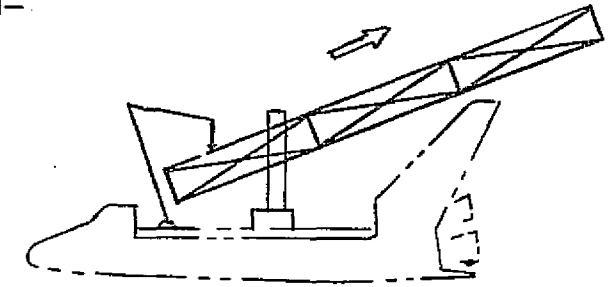
- MAX. LOAD IN STRUCTURAL BEAM = 48,720 N ULT COMP IUS LAUNCH TO GEO = 1.4g LIMIT ACCELERATION
- TEMPERATURE RANGE = 16°C TO – 123°C LEO
  5°C TO – 145°C GEO

GRUMMAN

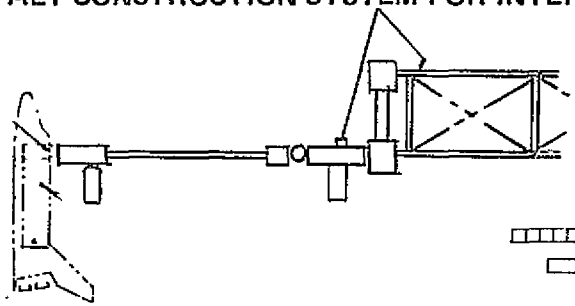
JG-460

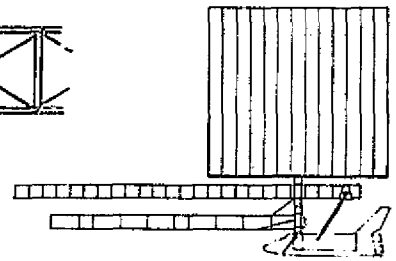
WHAT SIZE CONSTRUCTION SYSTEM?

SORTIE (FLT(S) CONSTRUCTION–
LOWER BOUND OF L.S.S.

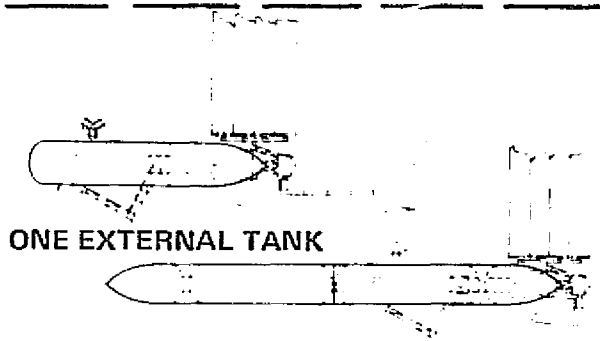


ALT CONSTRUCTION SYSTEM FOR INTERMEDIATE L.S.S.





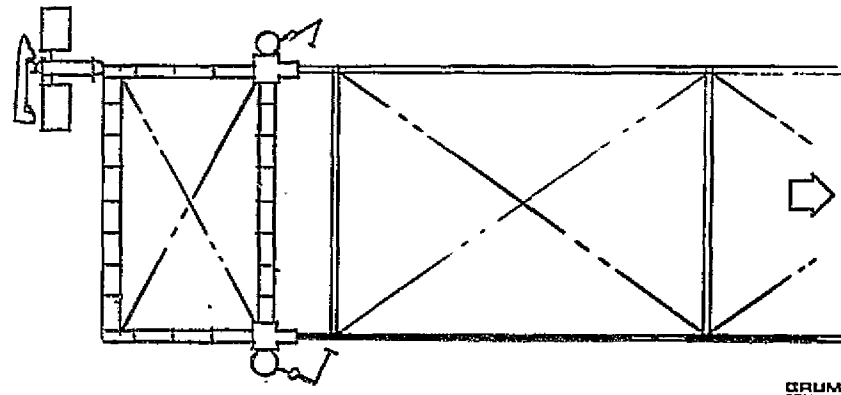
OCDA PLATFORM



ONE EXTERNAL TANK

TWO EXTERNAL TANKS

CONSTRUCTION SYSTEMS FOR UPPER
BOUND OF LSS (FULL SIZE SPS)



(MANY EXT. TANKS COMPRISING
CONSTR. SYST. FRAMEWORK?)

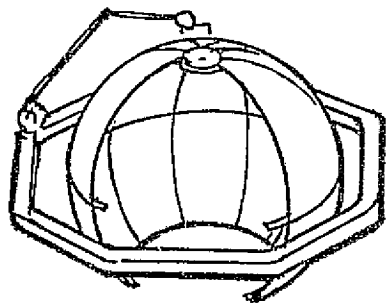
GRUMMAN

JG-464

CONSTRUCTION SYSTEM GENERIC CONCEPTS

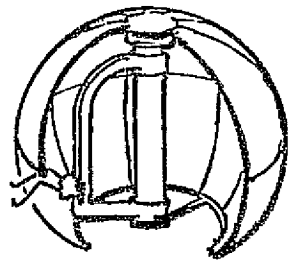
"WRAP AROUND" CONST. SYS.

- MAX SIZE FACILITY
- ACCESS TO ALL ZONES



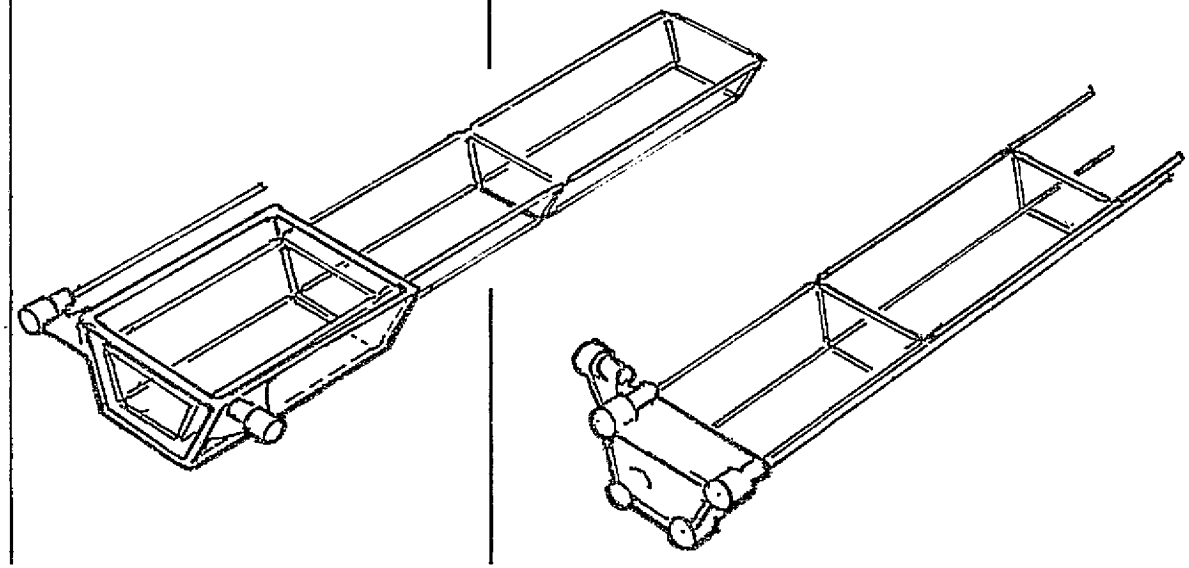
HYBRID CONST. SYS

- INTERMEDIATE SIZE
- ACCESS TO ONE ZONE AT A TIME
- ANY ZONE CAN BE REVISITED



"EXTRUSION" CONST. SYS.

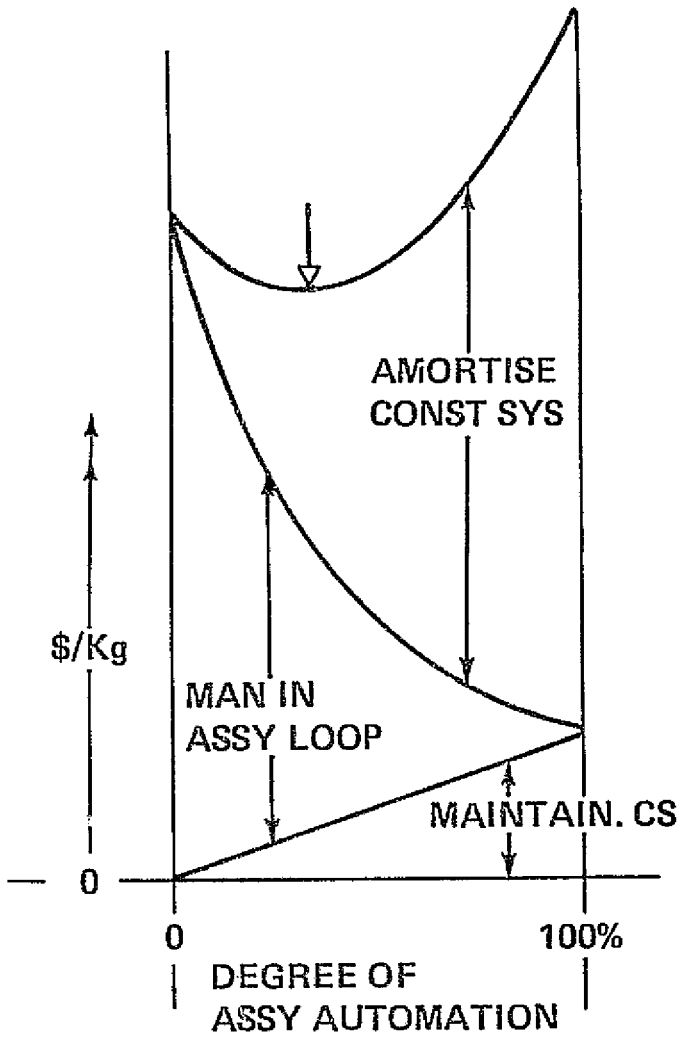
- MIN SIZE FACILITY
- ACCESS TO CONST. ZONE
  - LINEAR ASSY.
- REVISIT TO COMPLETED ZONES BY FREE FLYER/ EVA



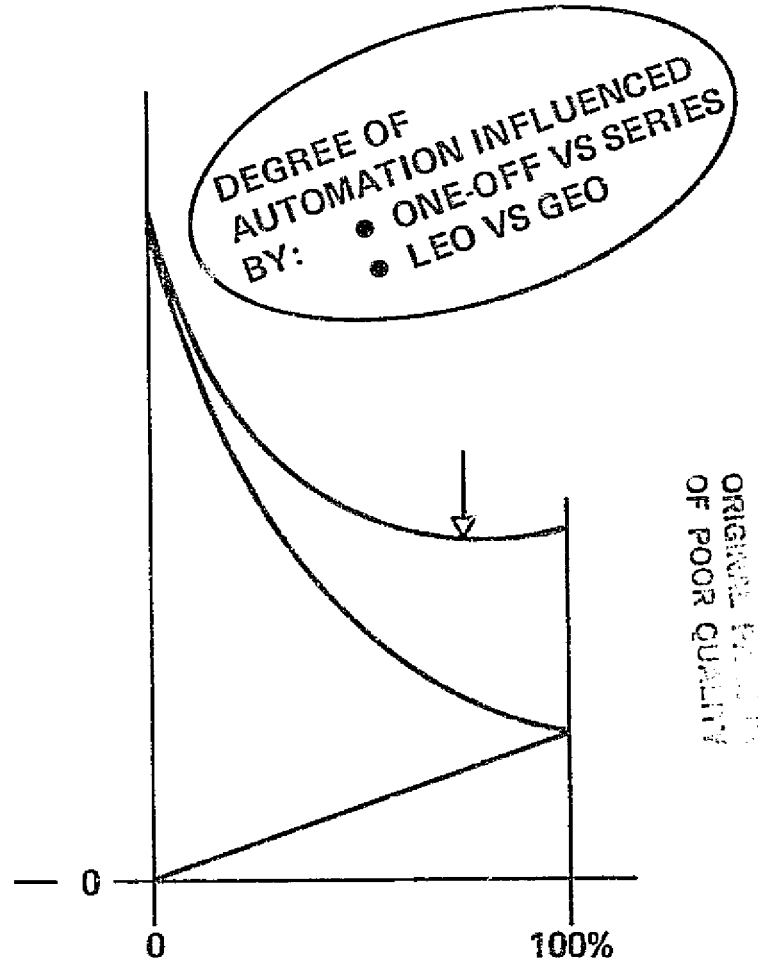
GRUMMAN

JG-436

CONSTRUCTION SYSTEM – OPTIMUM DEGREE OF AUTOMATION



MID '80s CONST ACTIVITY
ONE-OFF PROD



SPS FULL SIZE CONST
SERIES PROD

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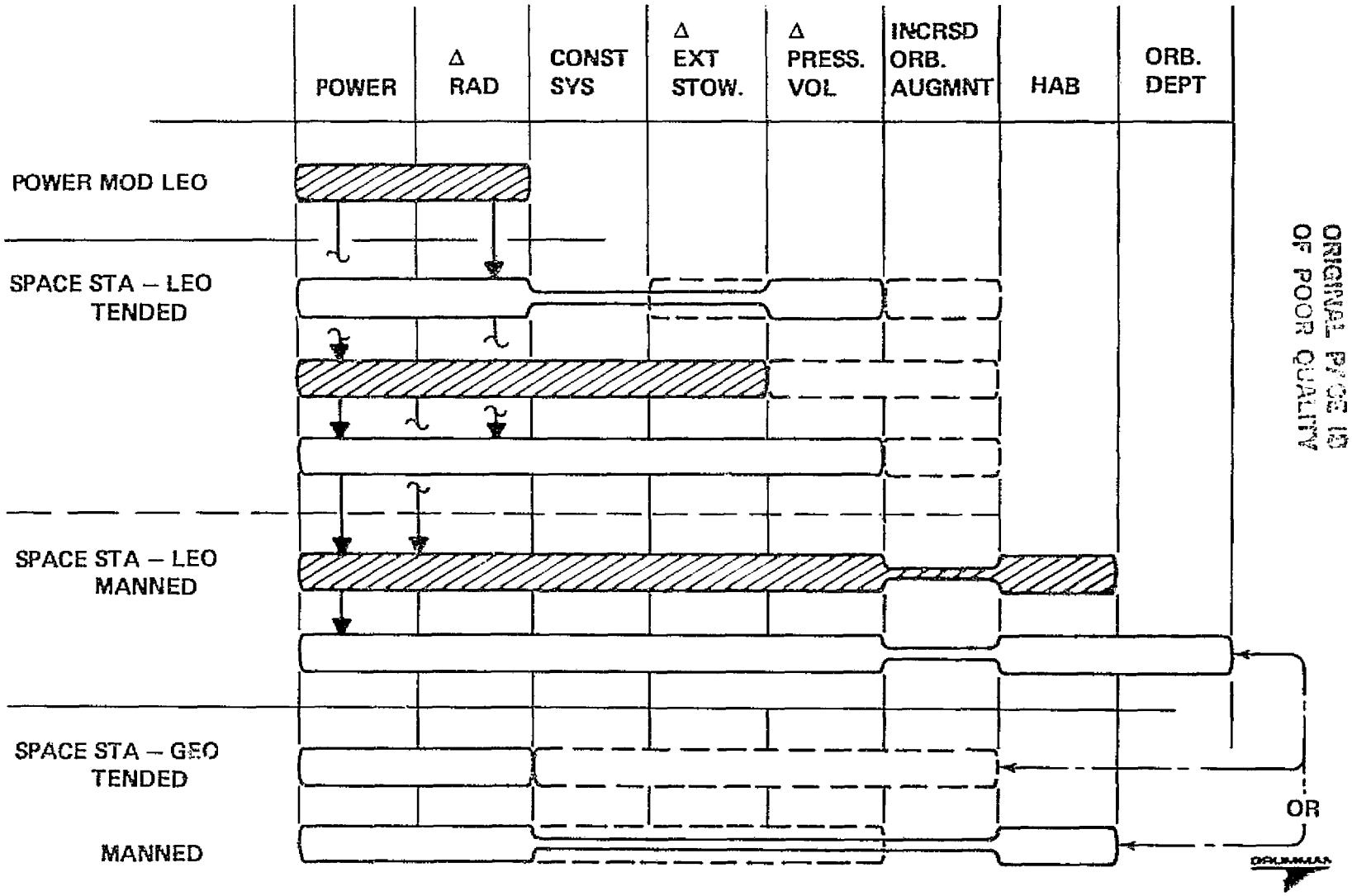
JG-403

SPACE STATION – MAJOR GROWTH OPTIONS



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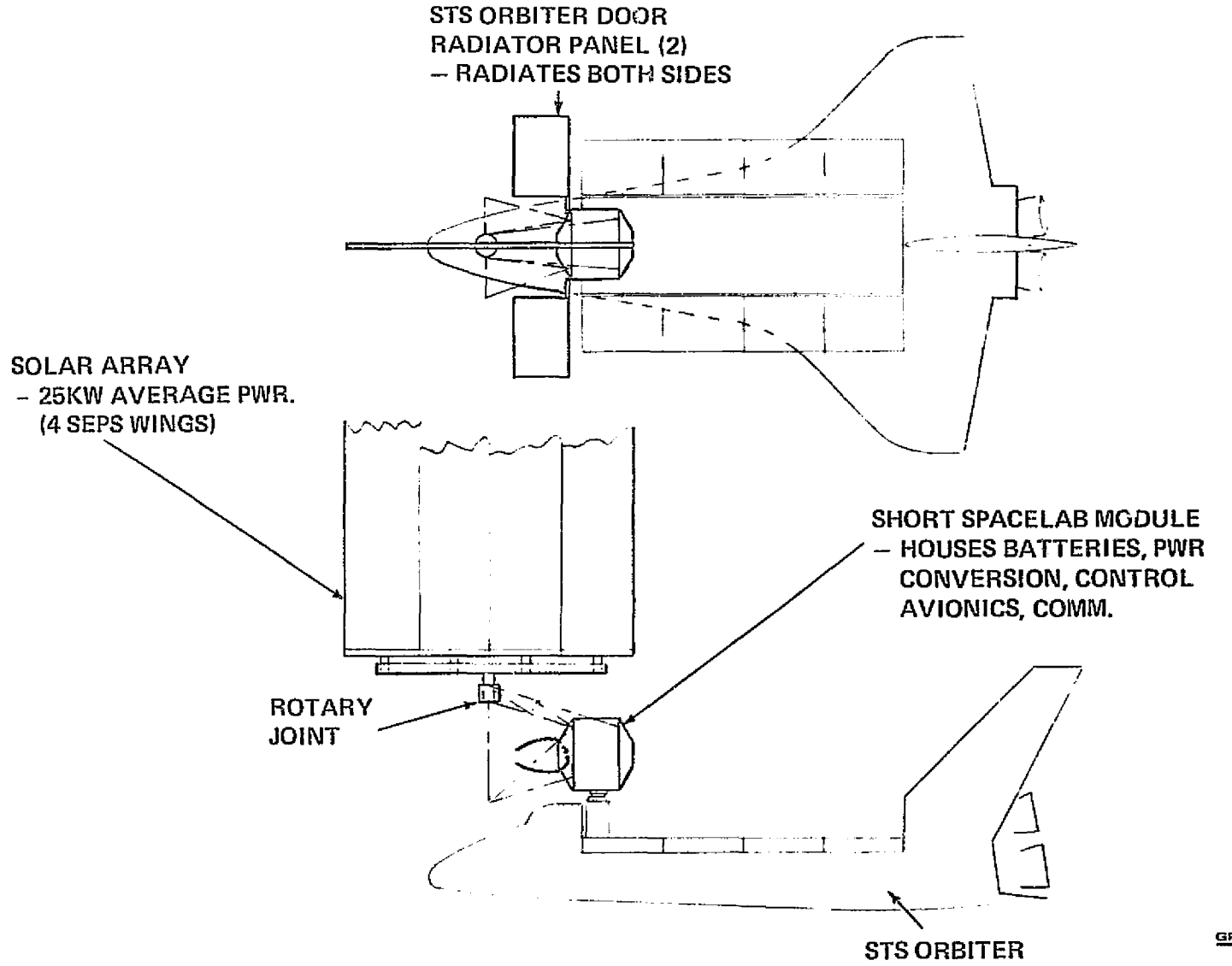
JG-404

25 KW POWER MODULE



JG-427

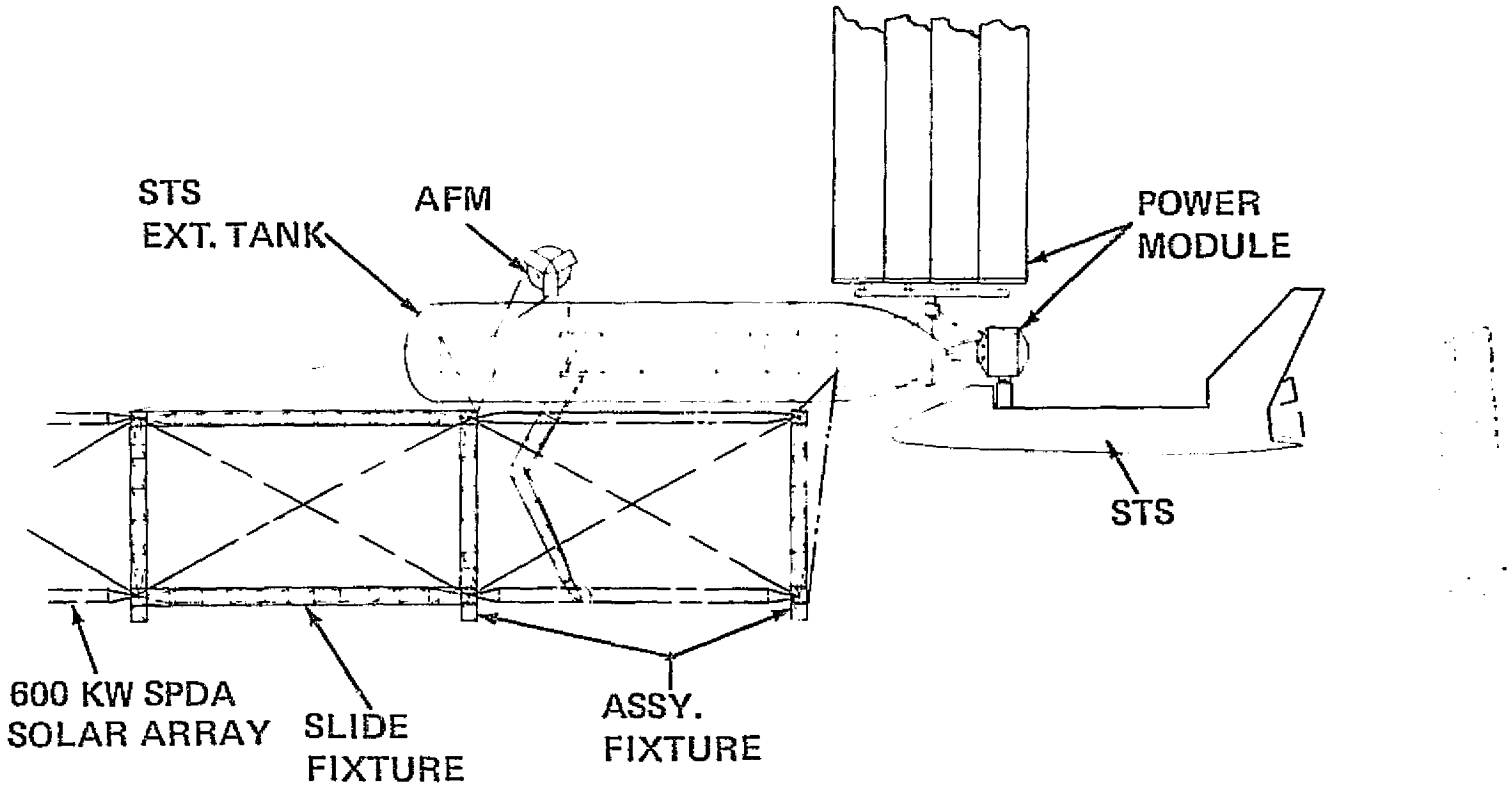
25 KW POWER MODULE WEIGHT SUMMARY

ITEM	WEIGHT Kg	
STRUCTURE	2,720	
INDUCED ENV PROTECT	170	
PROPULSION-RCS	340	
PRIME PWR - EPS	3,731	
AVIONICS - STAB & CONTROL	469	
COMM & TRACKING	59	
DATA MGT	283	
ENVIRON CONTROL	450	
PERSONNEL PROVISIONS	30	
DOCKING	422	
CONTINGENCY (25%)	2,169	
SUBTOTAL - DRY		10,843
PROPELLANT	1,208	
TOTAL - LAUNCH & ON ORBIT		12,051

GRUMMAN

JG-452

SPACE STATION TENDED MODE
CONSTRUCTION OF 600 KW SPDA SOLAR ARRAY



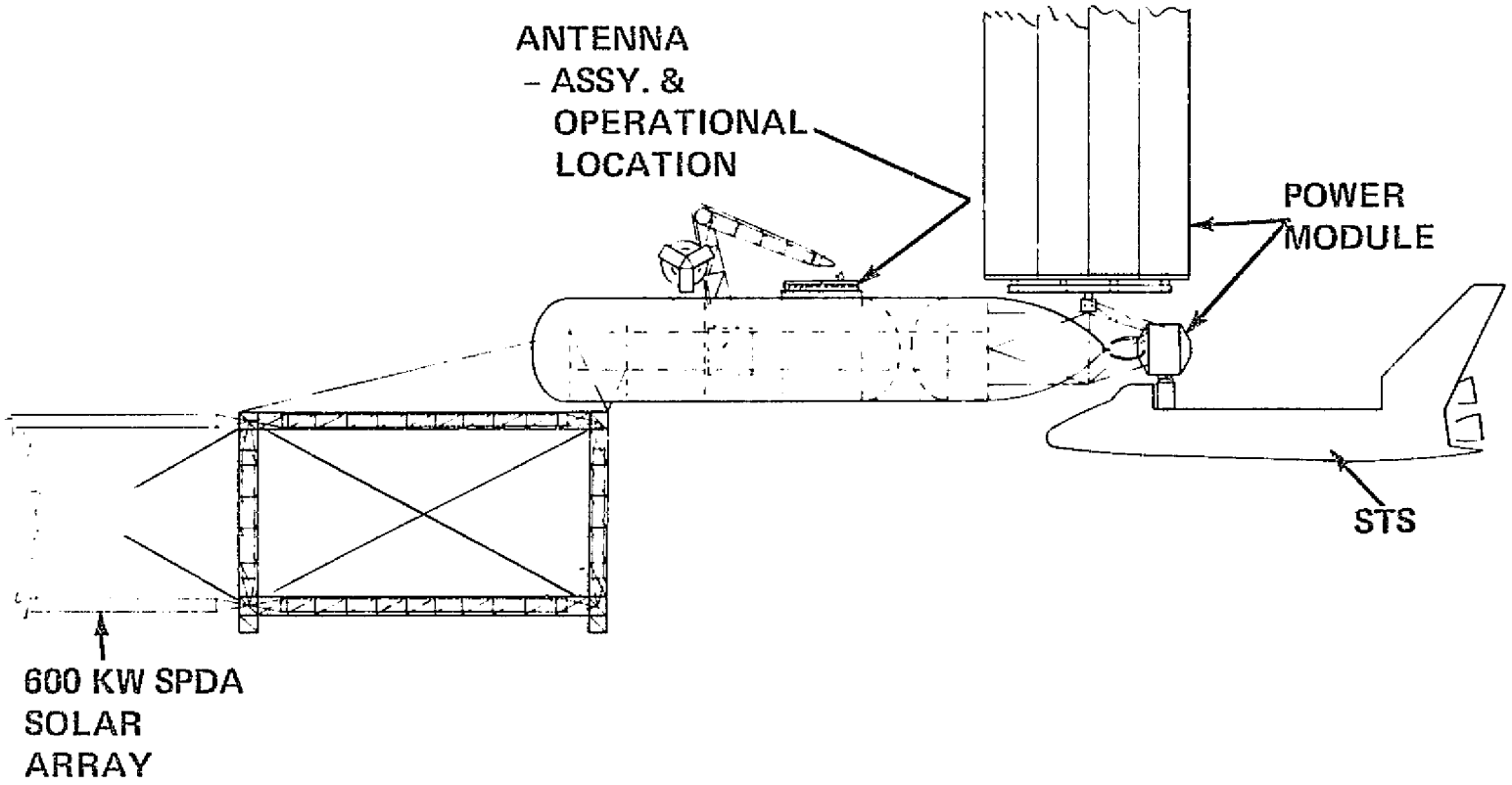
GRUMMAN

SPACE STATION TENDED MODE WEIGHT SUMMARY
MISSION EQUIPT. EXCLUDED

ITEM	WEIGHT Kg	
EXTERNAL TANK MODS	2,631	
AUTO. FAB MODULE & SUPPTS	3,691	
CONSTRUCTION AIDS	5,288	
CONTINGENCY (25%)	2,902	
SUBTOTAL - DRY		14,512
PROPELLANT	1,208	
TOTAL - LAUNCH TO AUGMENT PWR MODULE		15,720
EXTERNAL TANK	34,307	
POWER MODULE	10,843	
TOTAL - SPACE STATION ON ORBIT		60,870

GRUMMAN

SPACE STATION TENDED MODE
CONSTRUCTION OF 600 KW SPDA HIGH PWR. DENSITY ANTENNA



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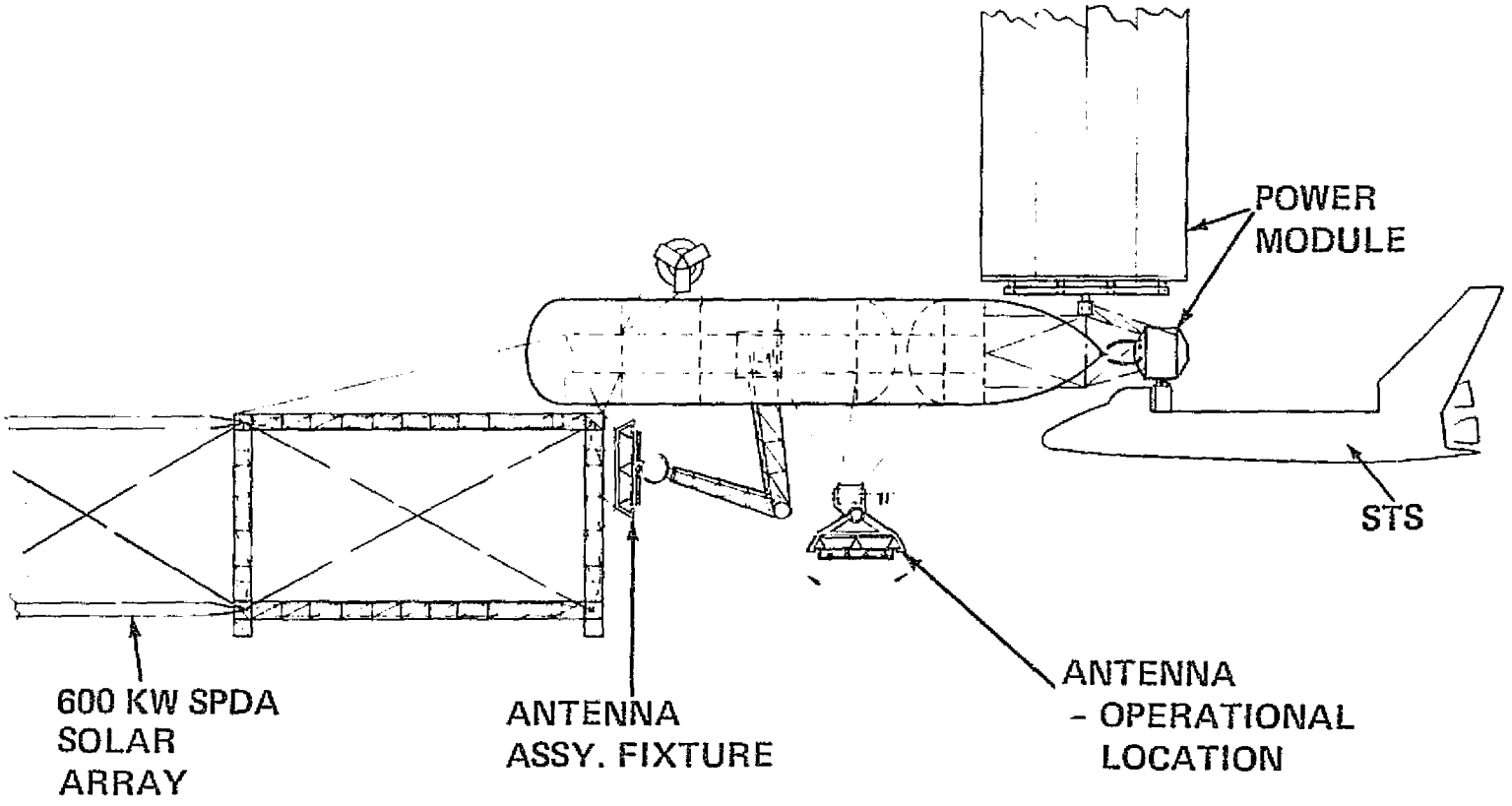
GRUMMAN

JG-428

SPACE STATION TENDED MODE
CONSTRUCTION OF 600 KW SPDA LINEAR ANTENNA



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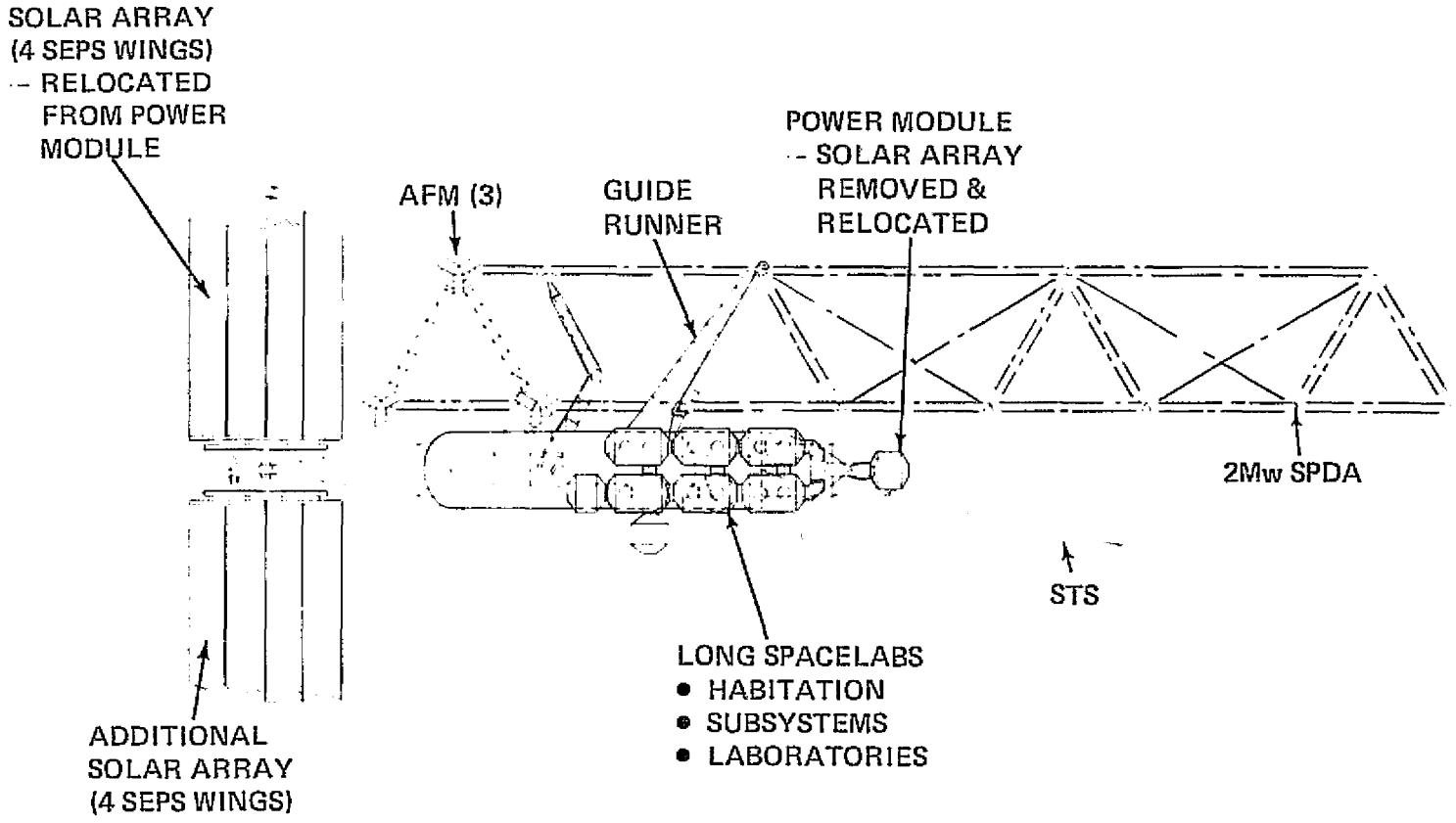
GRUMMAN

SPACE STATION MANNED MODE
CONSTRUCTION OF 2.2Mw SPDA



GRUMMAN

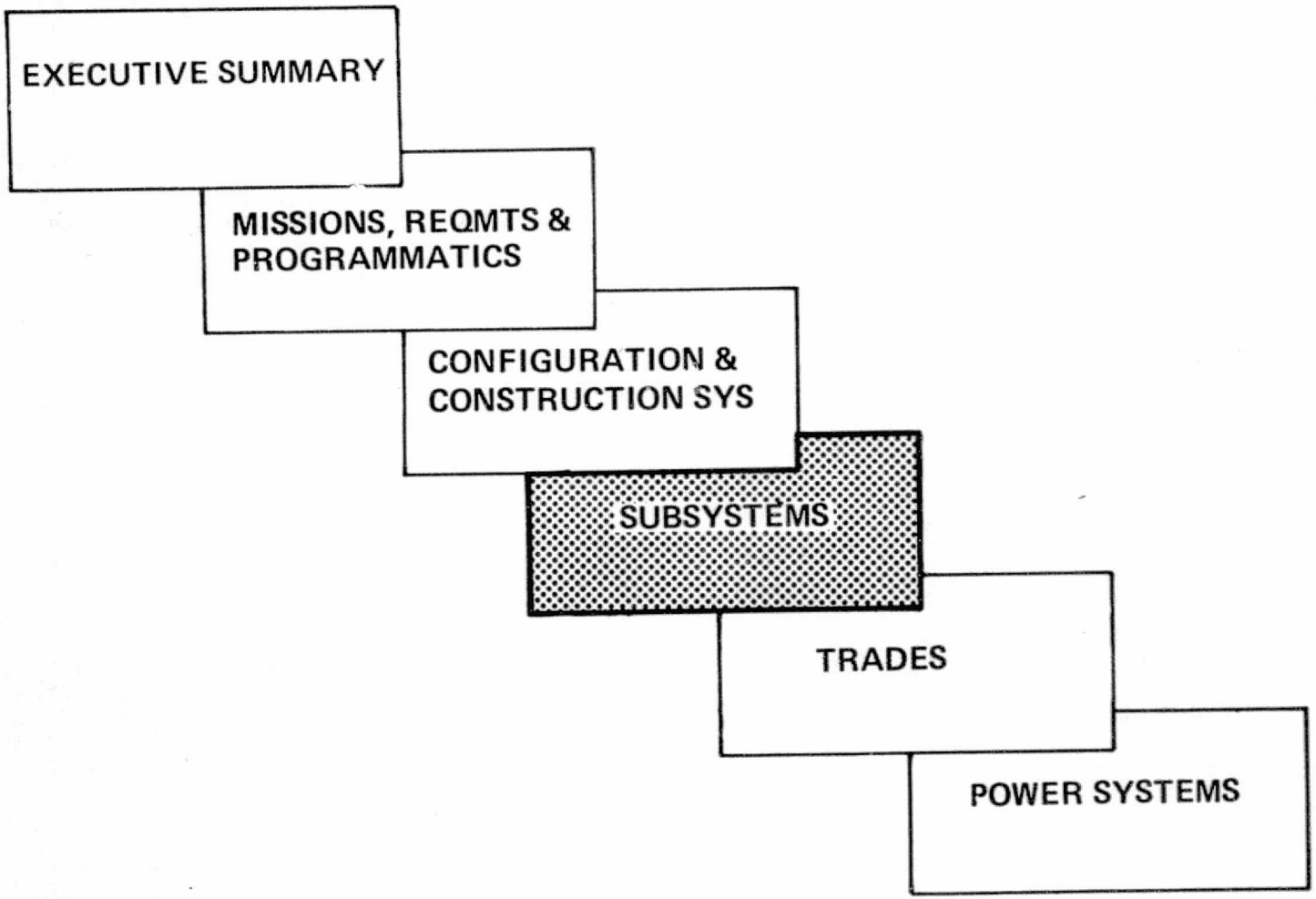
JG-426

SPACE STATION MANNED MODE WEIGHT SUMMARY
MISSION EQUIPT. EXCLUDED

ITEM	WT(Kg)	
STRUCTURE	34,100	
INDUCED ENV. PROTECT.	1,373	
PRIME PWR – EPS	9,146	
AVIONICS – COMM & TRACKING	244	
– DATA MGT.	604	
ENVIRON. CONTROL	3,900	
PERSONNEL PROVISIONS	2,081	
AUTO. FAB. MODULES & SUPPTS	7,382	
CONSTRUCTION AIDS	478	
DOCKING	422	
SPARES	930	
CONTINGENCY (25%)	15,165	
SUBTOTAL – DRY		75,825
CREW & EXPENDABLES	5,144	
PROPELLANT	1,208	
TOTAL-LAUNCH TO AUGMENT TENDED SPACE STN		82,177
SPACE STATION TENDED MODE	59,662	
TOTAL-SPACE STATION ON ORBIT		141,839

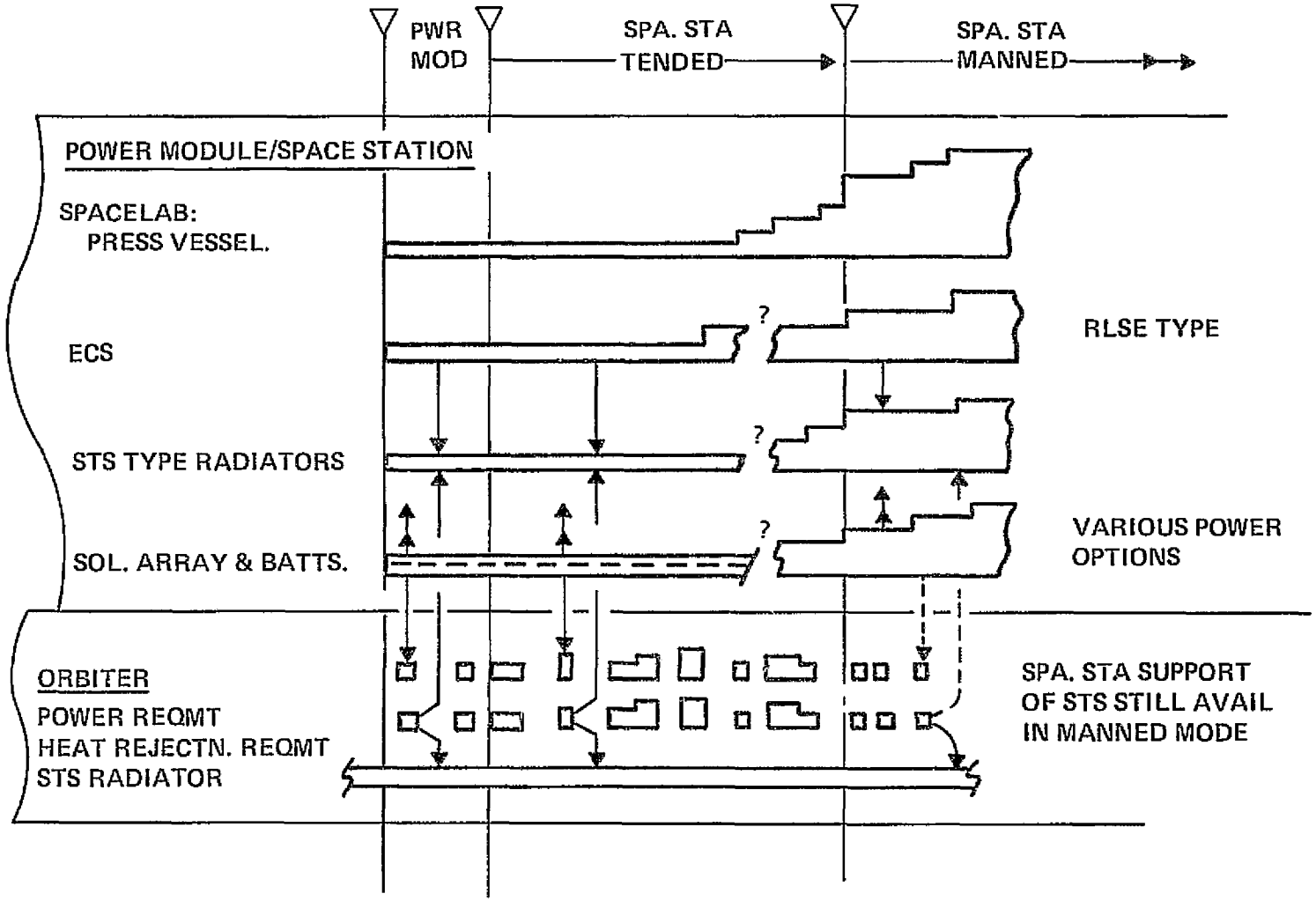
GRUMMAN

AGENDA SPACE STATION PROGRAM REVIEW MEETING
19 APRIL 1977



GRUMMAN

SPACE STATION ECLS & POWER – POTENTIAL SUBSYSTEM CHANGES IN THE TENDED PHASE



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GRUMMAN

JG-455

SPACE STATION REQUIREMENTS

GENERAL	EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED
POWER REQD, KW	22	22	55
CREW SIZE	(4)	(4-7)	10
NUMBER OF MODULES			
• SHORT SPACELAB	1	2	6
• LONG SPACELAB		2	6
MISSIONS			
• SCIENTIFIC	√	√	√
• CONSTRUCTION			
– SMALL INTERMEDIATE	√		
– MED INTERMEDIATE		√	
– LARGE INTERMEDIATE			√
• SPACE MANUFACTURE			
– PROTOTYPE		√	
– PRODUCTION			√

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JG-408

SPACE STATION SUBSYSTEM REQUIREMENTS

SUBSYSTEM	REQUIREMENTS	EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED
STRUCTURE	• PROVIDE VOLUME FOR:			
	– EXPERIMENTATION	√	√	√
	– SUBSYSTEMS	√	√	√
	– SPACE MANUFACTURE		√	√
	– HABITATION			√
	• PROVIDE EXTERNAL AREA FOR:			
	– EXPERIMENTATION	√	√	√
	– CONSTRUCTION	√	√	√
	– STOWAGE	√	√	√
	– ORBITAL DEPOT			√
FLIGHT CONTROL				
• RCS	• ORBITAL MAINTENANCE	√	√	√
	• STATIONKEEPING	√	√	√
• STABILIZ-ATION & CONTROL	• ORBITAL MAINTENANCE	√	√	√
	• STATIONKEEPING	√	√	√
	• FINE POINTING			√
	• STABLE PLATFORM			√

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SPACE STATION SUBSYSTEM REQUIREMENTS (CONT'D)

SUBSYSTEM	REQUIREMENTS	EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED
EPS	• SUPPLEMENT SHUTTLE	√	√	
	• SUPPORT MISSION REQMTS	√	√	√
	• SUPPORT INDEPENDENT SPACE PLATFORM			√
AVIONICS				
• COMM & TRACKING	• PROVIDE RF COMM (TELEMETRY, RANGING, COMMAND WITH NASA STDN, TDRSS & SHUTTLE	√	√	√
	• PROVIDE HARDLINE COMM WITH DOCKED ORBITER	√	√	√
	• PROVIDE DUPLEX VOICE COMM CHERRY PICKER/ORBITER	√	√	√
	• PROVIDE AUDIO/VOICE AMONG CREW STATIONS			√
	• CLOSED CIRCUIT TV WITH GROUND LINK			√
	• PROVIDE RF LINKS TO SUPPORT EVA			√
• DATA MGMT	• TELEMETRY FOR SYSTEM & MISSION STATUS	√	√	√
	• RECEIVE, STORE & TRANSFER COMMANDS FROM GROUND AND/OR SHUTTLE	√	√	√
	• ONBOARD PROCESSING TO SUPPORT FLT/ MISSION FUNCTIONS			√
	• MONITORING OF SYSTEMS & CONFIG CONT FUNCTIONS			√
	• DISPLAYS & CONTROLS FOR SYSTEM, CONFIG & MISSION EXPERIMENTS			√

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SPACE STATION SUBSYSTEM REQUIREMENTS (CONT'D)

SUBSYSTEM	REQUIREMENTS	EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED
ECLS				
• ATMOSPHERE REVITALIZATION	• SUPPLEMENT SHUTTLE	√	√	
	• REMOVAL OF METABOLIC C_{O_2}	√	√	√
	• RECLAMATION OF O_2			√
	• GENERATION OF O_2			√
	• REMOVAL OF TRACE CONTAMINANTS			√
	• ATMOS PRESSURE & COMPOSITION CONTROL	√	√	√
• WATER MGMT	• URINE COLLECTION & RECLAMATION			√
	• STERILIZATION & MONITORING			√
	• WASH WATER COLLECTION & RECLAMATION			√
• WASTE MGMT	• VACUUM DRY FECAL WASTE			√
• THERMAL CONT	• PROVIDE ACTIVE WASTE HEAT REJECTION	√	√	√
	• PROVIDE ACTIVE THERMAL CONTROL FOR:			
	– ATMOSPHERE	√	√	√
	– COLD PLATE COOLED ELECTRONICS	√	√	√
	– MISSION EQUIPMENT		√	√

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SPACE STATION SUBSYSTEM REQUIREMENTS (CONT'D)

SUBSYSTEM	REQUIREMENTS	EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED
PERSONNEL PROVISIONS	• MOBILITY AIDS; HAND RAILS, TOEHOLDS ETC	√	√	√
	• COMMAND/CONTROL CENTER		√	√
	• WORK STATIONS		√	√
	• INDIVIDUAL CREW QUARTERS			√
	• GALLEY/WARDROOM/RECREATION EXERCISE AREAS			√
	• PERSONAL HYGIENE AND LAUNDRY FACILITIES			√
	• HOUSEKEEPING PROVISIONS			√
	• EMU'S/MMU'S			√
	• AIRLOCK			√
CONSTRUCTION AIDS				
• SPINE	• CONSTRUCTION PLATFORM	√	√	√
• CHERRY PICKER	• LONG REACH; STABLE WORK STATION	√	√	√
• AFM	• PRODUCE 1M BEAMS	√ (1)	√	√ (3)

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SUBSYSTEM CHANGES
EARLY TENDED TO PERMANENTLY MANNED

SUBSYSTEM	CHANGES		
	EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED
STRUCTURE	GROWS WITH CONFIGURATION & MISSION REQMTS		
FLIGHT CONTROL	SOFTWARE CHANGES		
EPS	ADDITIONAL POWER GENERATION & STORAGE		
AVIONICS	STEP GROWTH WHEN MANNED		
ENVIRONMENTAL CONTROL	STEPPED GROWTH AS REQ'TS INCREASE		
PERSONNEL PROVISIONS	GROWS WITH HABITABLE VOLUME		
CONSTRUCTION AIDS	AS REQ'D TO SATISFY MISSIONS		

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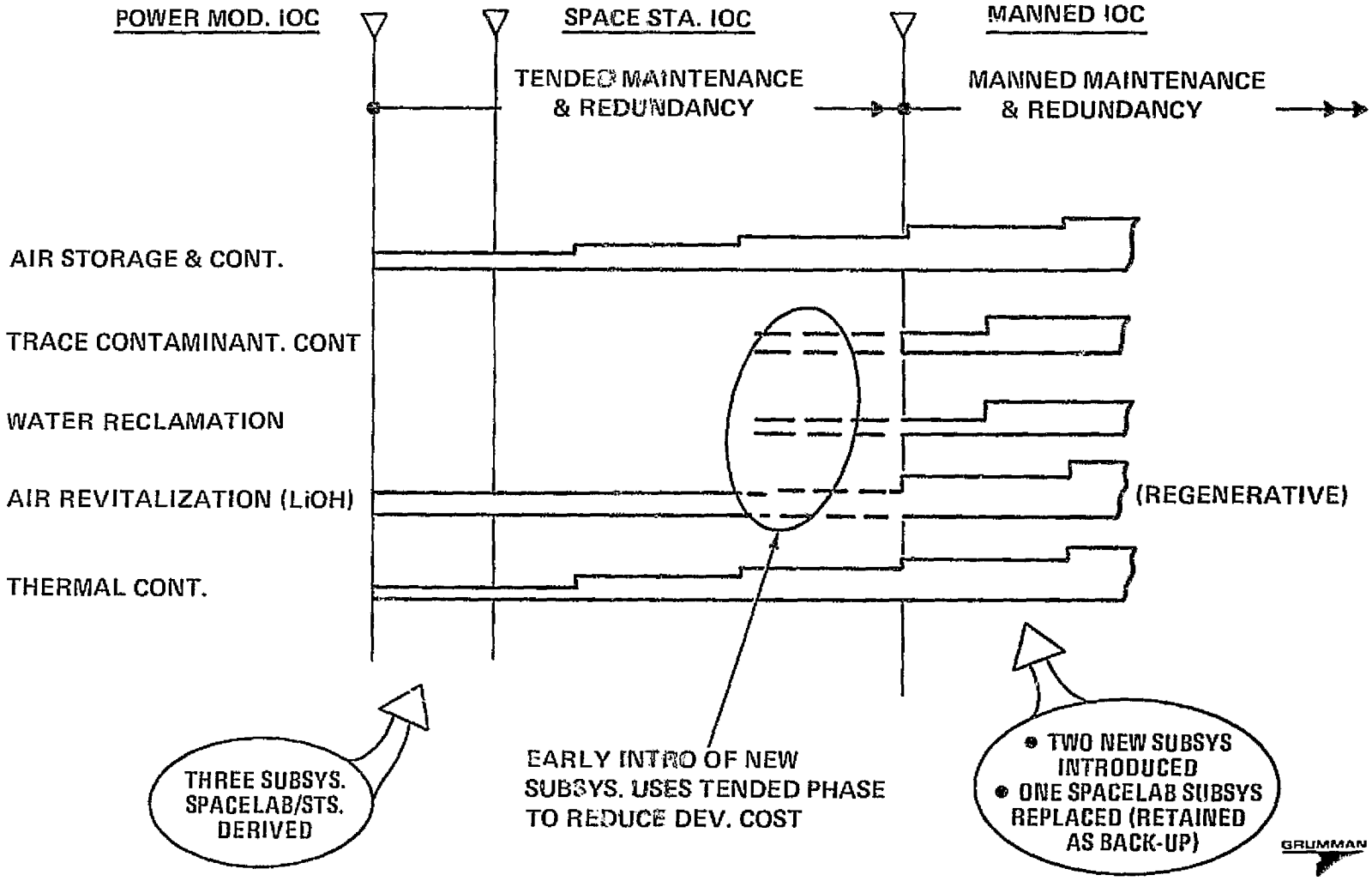
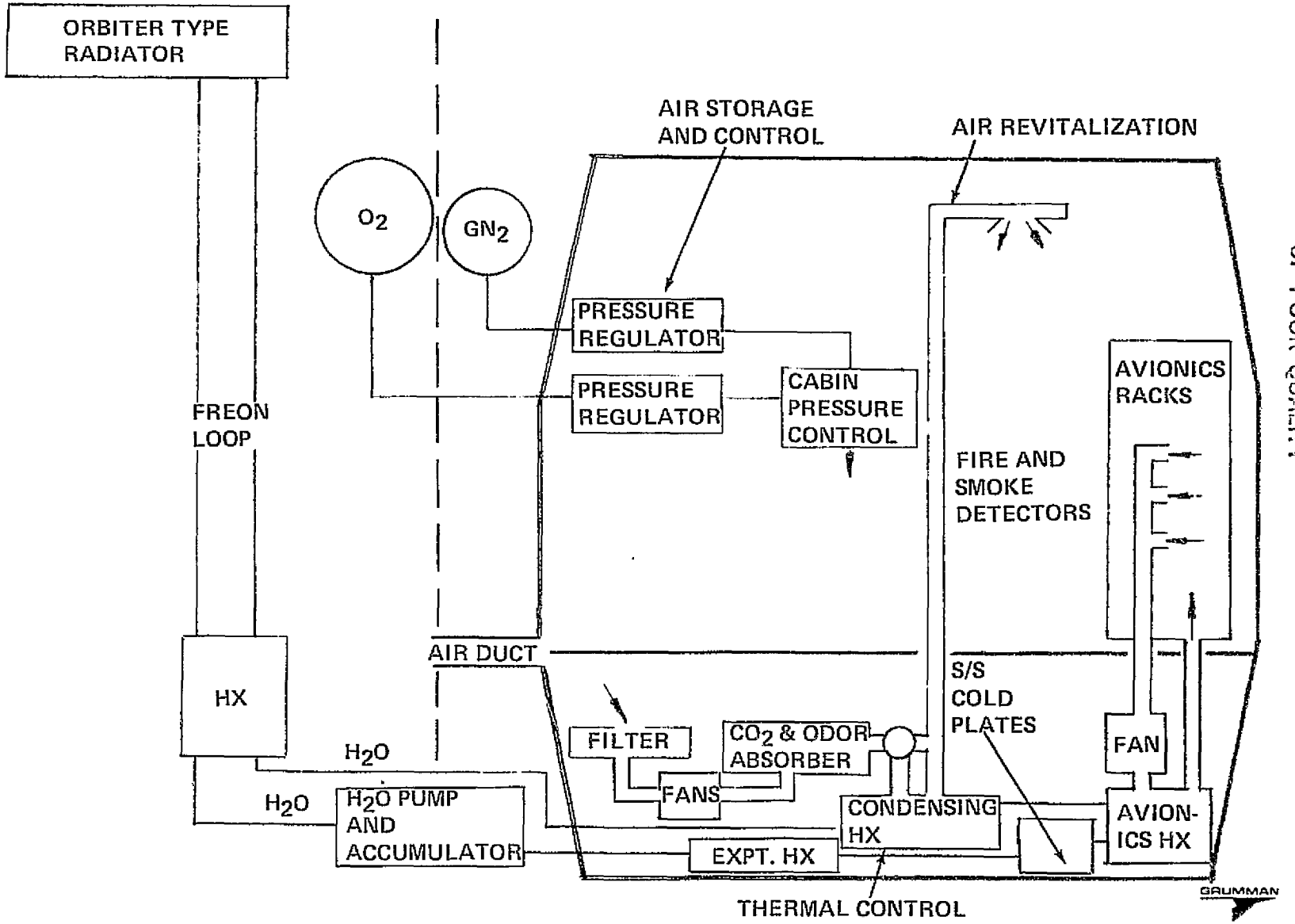
ECLS GROWTH THRU TENDED TO MANNED MODE



JG457

SPACELAB TYPE ECS



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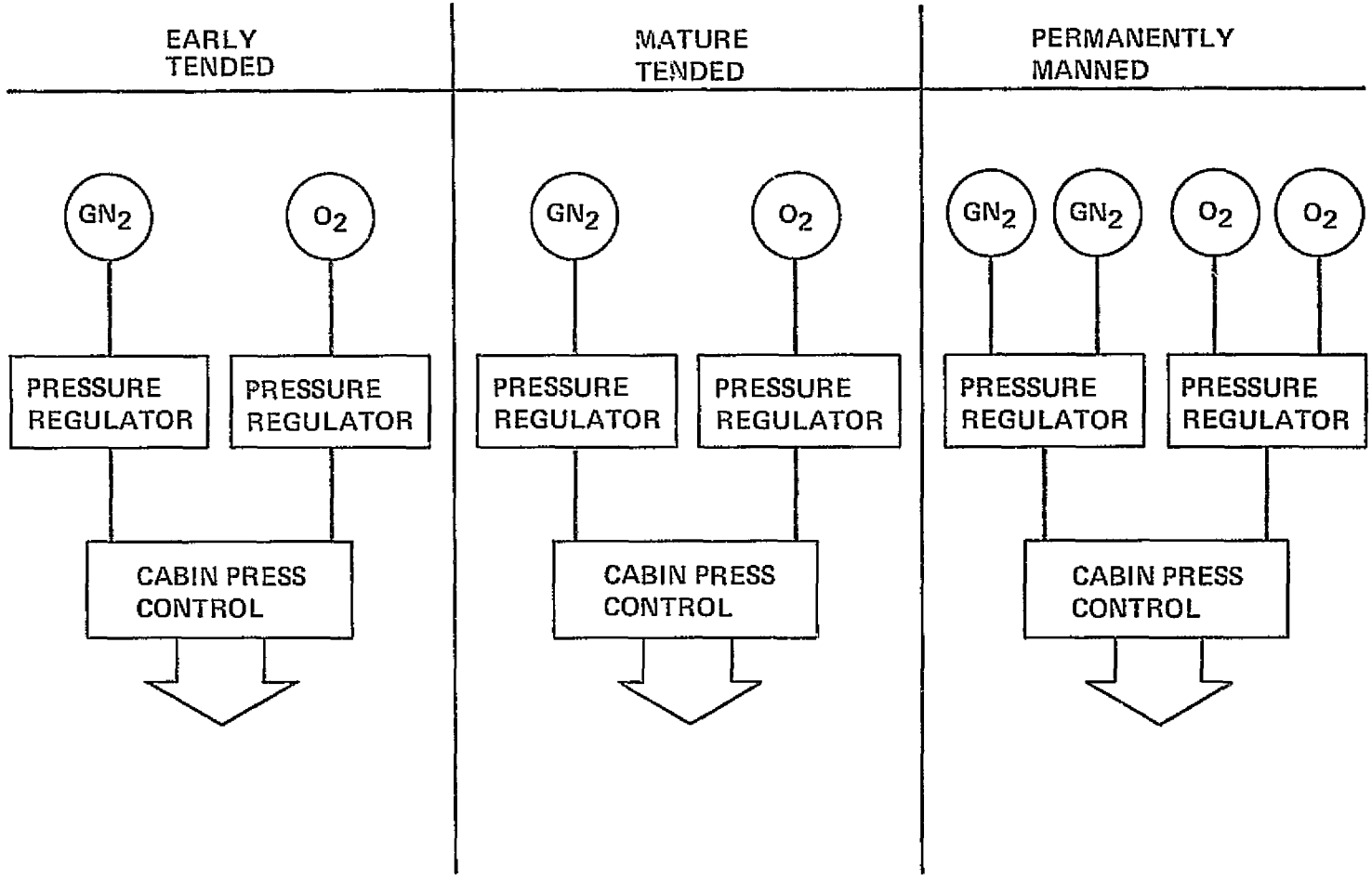
JG-466

ENVIRONMENTAL CONTROL
AIR STORAGE AND CONTROL



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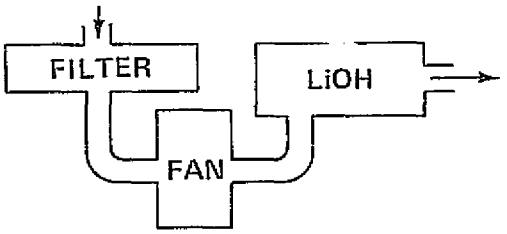
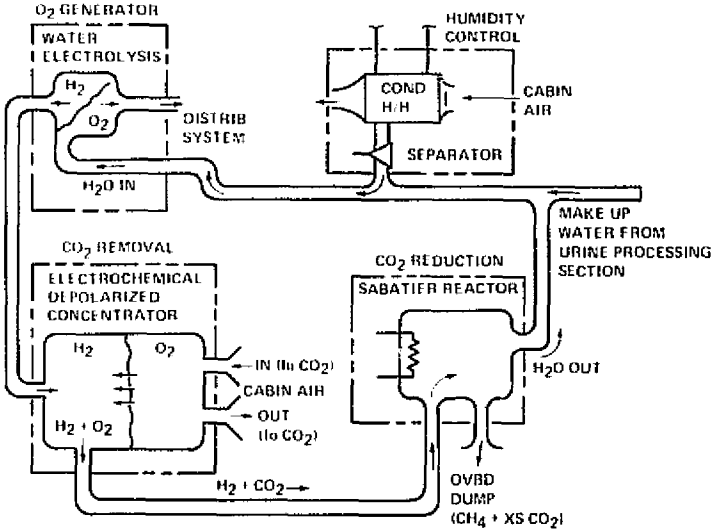
ENVIRONMENTAL CONTROL
ATMOSPHERE REVITALIZATION

EARLY TENDED



MATURE TENDED

PERMANENTLY MANNED



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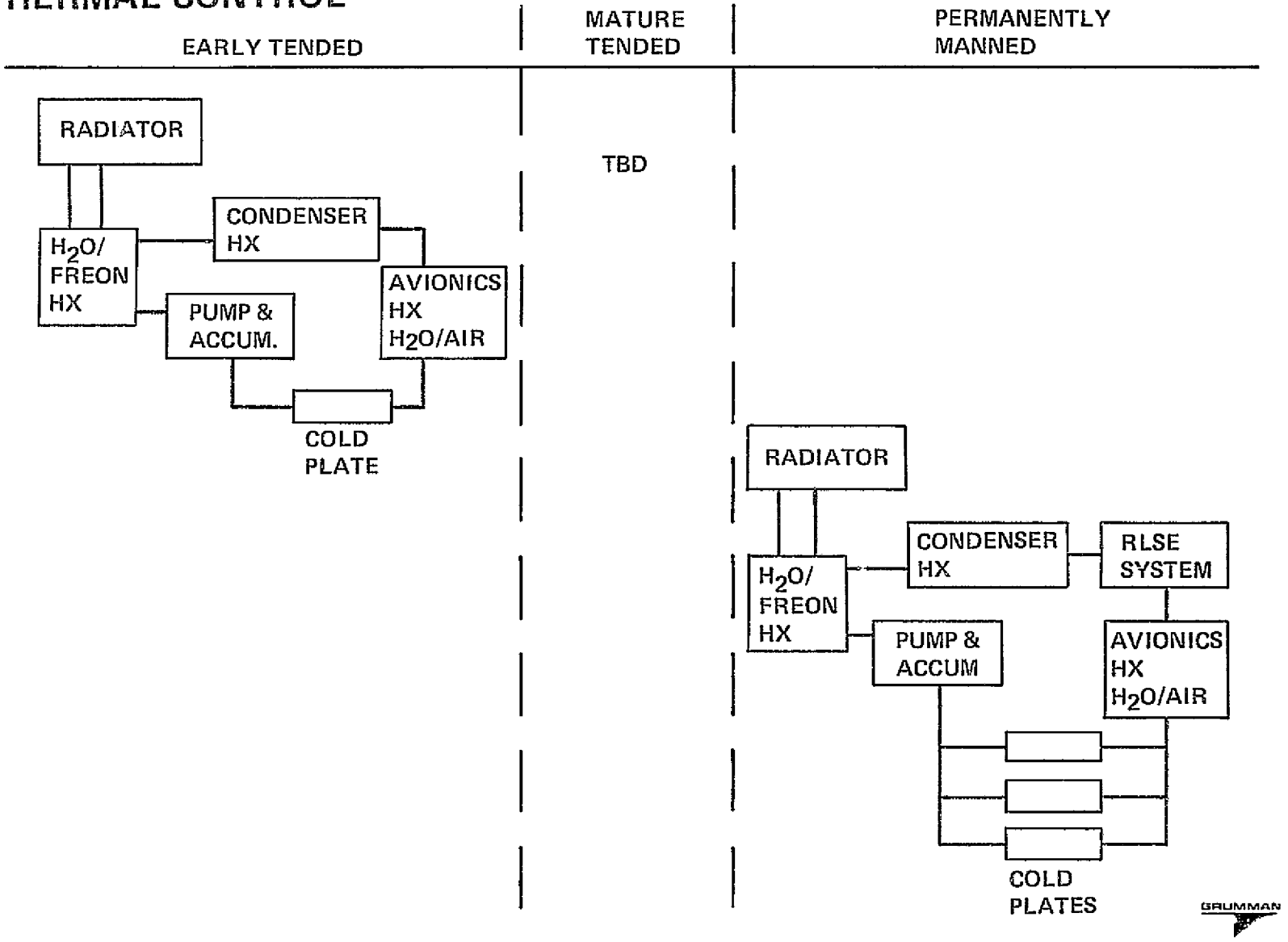
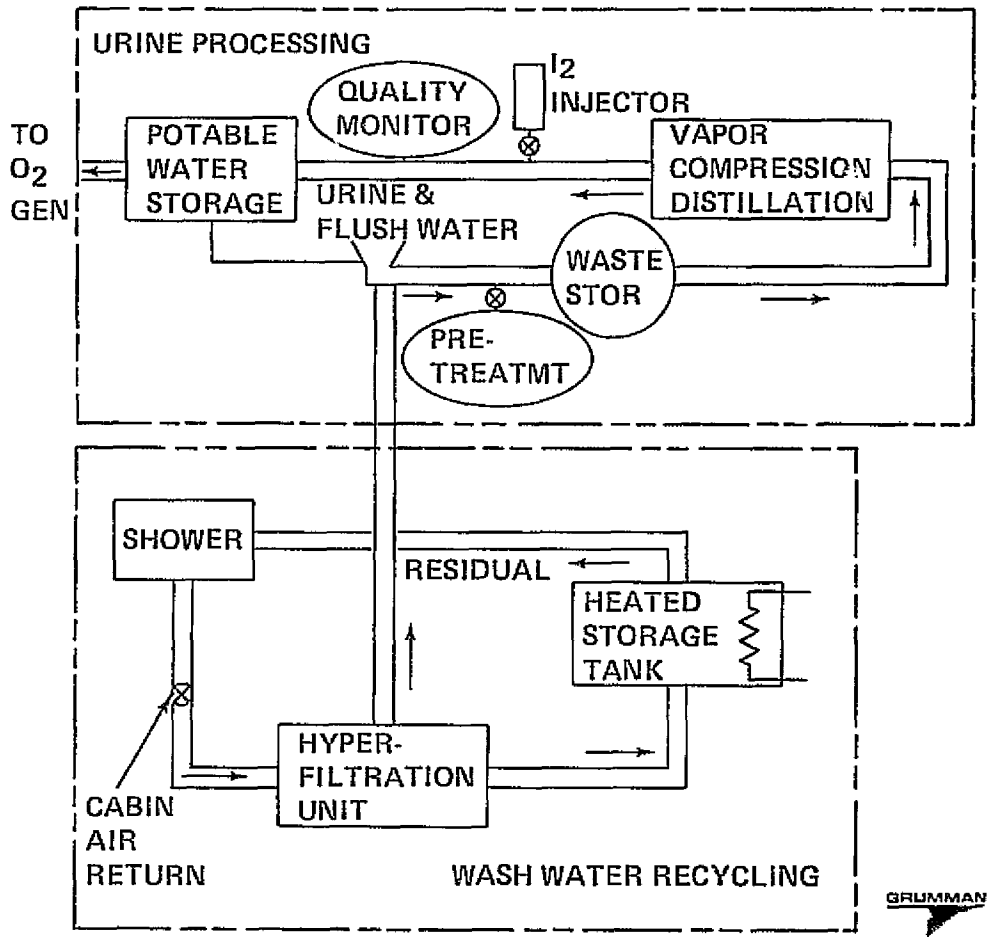
ENVIRONMENTAL CONTROL
THERMAL CONTROL



JG-467

ENVIRONMENTAL CONTROL
WATER RECLAMATION

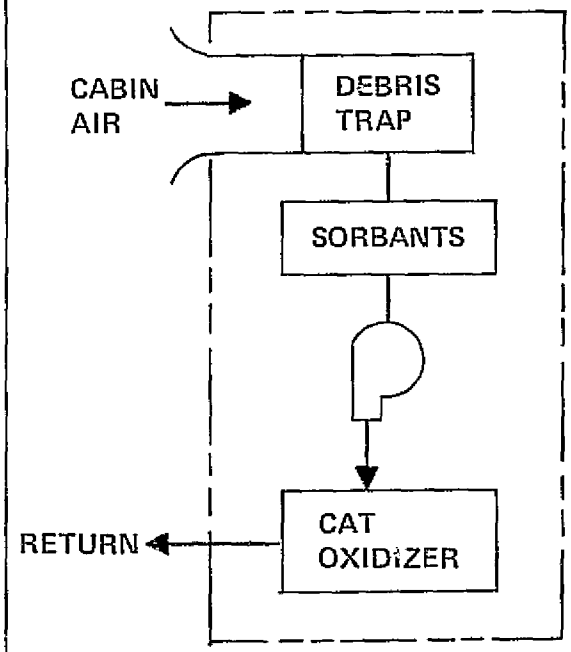
EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED



JG-422

ENVIRONMENTAL CONTROL
TRACE CONTAMINANT CONTROL

EARLY TENDED	MATURE TENDED	PERMANENTLY MANNED



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JG-458

AVIONICS SUBSYSTEMS

AVIONICS SUBSYSTEMS GROUND RULES

- CONSIDER ONLY COMMUNICATIONS/TRACKING, & DATA MANAGEMENT (S & C TREATED UNDER FLIGHT CONTROL)
- CONSIDER REQMTS FOR TENDED MODE SPACE STATION EVOLVING INTO THE MANNED MODE SPACE STATION
- UTILIZE EXISTING HARDWARE, WHERE POSSIBLE

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MISSION DRIVERS ON SPACE STATION AVIONICS

	SPACE STATION	
	TENDED MODE	MANNED MODE
• SPDA CONSTRUCTION	√	√
• PSP CONSTRUCTION	√	
• SPACE MANUFACTURING	√ *	√
• SPACE SCIENCE	√ *	√
• LIFE SCIENCES	–	√

*LIMITED CAPABILITY

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AVIONICS SUBSYSTEM FUNCTIONAL REQUIREMENTS
COMMUNICATIONS & TRACKING

SPACE STATION-TENDED MODE

- PROVIDE RF COMMUNICATIONS (TELEMETRY, RANGING, COMMAND) WITH NASA STDN, TDRSS, & ORBITER
- PROVIDE HARDLINE COMMUNICATIONS WITH DOCKED ORBITER
- PROVIDE CHERRYPICKER CAPSULE CREWMAN WITH DUPLEX VOICE COMMUNICATIONS (RF & HARDLINE) WITH ORBITER

SPACE STATION-MANNED MODE (ALL ABOVE PLUS)

- PROVIDE AUDIO/VOICE COMMUNICATIONS AMONG CREW STATIONS WITHIN & BETWEEN SPACE STATION MODULES
- GENERATE, TRANSMIT & DISTRIBUTE CLOSED CIRCUIT TELEVISION & INTERCONNECT WITH THE GROUND VIA THE RF LINK
- PROVIDE RF LINKS TO SUPPORT EVA
- PROVIDE HIGH DATA RATE LINK TO GND VIA TDRS

AVIONICS SUBSYSTEM FUNCTIONAL REQUIREMENTS (CONT'D)
DATA MANAGEMENT

SPACE STATION-TENDED MODE

- PROVIDE REAL TIME & STORED TELEMETRY FOR DETERMINING SYSTEM & MISSION STATUS INFORMATION (ON BOARD CHECKOUT)
- PROVIDE CAPABILITY TO RECEIVE, STORE & TRANSFER COMMANDS FROM GROUND OR ORBITER TO MISSION HARDWARE OR ON-BOARD SPACE STATION SYSTEMS (e.g. S&C)

SPACE STATION-MANNED MODE (ALL ABOVE PLUS)

- PROVIDE ONBOARD PROCESSING* TO SUPPORT FLIGHT & MISSION FUNCTIONS (e.g. DISPLAYS, MISSION EXPERIMENT PROCESSING)
- PROVIDE DISPLAYS & CONTROLS FOR EVALUATING & SPACE STATION SYSTEMS & MISSION EXPERIMENTS

*INCLUDES COMPUTING, STORING, ROUTING & ACQUISITION FUNCTIONS

POTENTIAL HARDWARE INVENTORY

COMMUNICATIONS & TRACKING

EQUIPMENT	QUANTITY	UNIT WT(LB)	POWER (W)	HARDWARE SOURCE
SPACE STATION-TENDED MODE				
• TRANSPONDER	2	23	15	ORBITER
• ANTENNAS	5	2	N/A	ORBITER
• POWER AMPLIFIER	1	30	25	ORBITER
• ANTENNA SWITCH ASSEMBLY	1	8	–	ORBITER
• SIGNAL PROCESSOR	2	18	12	ORBITER
• TV CAMERA	1	2	20	ORBITER
SPACE STATION-MANNED MODE				
• WIDEBAND TRANSMITTER • FM TRANSMITTER	1	142	300	ORBITER(MOD)
• TDRS ANTENNA	2	25	N/A	ORBITER
• TDRS ANTENNA MAST	2	150	N/A	ORBITER(MOD)
• SIGNAL PROCESSOR	1	18	8	ORBITER(MOD)
• AUDIO INTERCOM				
– AUDIO CONTROL UNIT	1	4	2	ORBITER
– AUDIO TERMINAL UNIT	6	4	2	ORBITER
• CLOSED CIRCUIT TV				
– TV CAMERAS	4	2	20	ORBITER
– VIDEO SWITCHING UNIT	1	6	N/A	ORBITER
– VIDEO MONITOR	1	35	60	ORBITER

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POTENTIAL HARDWARE INVENTORY (CONT'D)
DATA MANAGEMENT

EQUIPMENT	QUANTITY	UNIT WT(LB)	POWER (W)	HARDWARE SOURCE
SPACE STATION-TENDED MODE				
• PROCESSOR	2	59	300	ORBITER(MOD)
• PCM UNIT	2	30	30	ORBITER
• SIGNAL CONDITIONING	TBD	30	40	ORBITER(MOD)
• MDM	TBD	30	30	ORBITER
• MASTER TIMING UNIT	1	26	30	ORBITER
• TRANDUCERS	TBD	TBD	TBD	OFF THE SHELF
• RECORDER	1	30	45	ORBITER
SPACE STATION - MANNED MODE				
• GENERAL PURPOSE COMPUTER	2	59	337	ORBITER
• DISPLAY ELECTRONICS	1	60	84	ORBITER
• CRT/KEYBOARD	1	50	120	ORBITER
• CAUTION & WARNING UNIT	1	22	30	ORBITER
• C&W ANNUNCIATOR UNIT	1	6	15	ORBITER
• MASTER ALARM UNIT	1	10	15	ORBITER
• REMOTE CONTROL & DISPLAY	TBD	60	120	NEW
• TELETYPE	1	15	15	ORBITER

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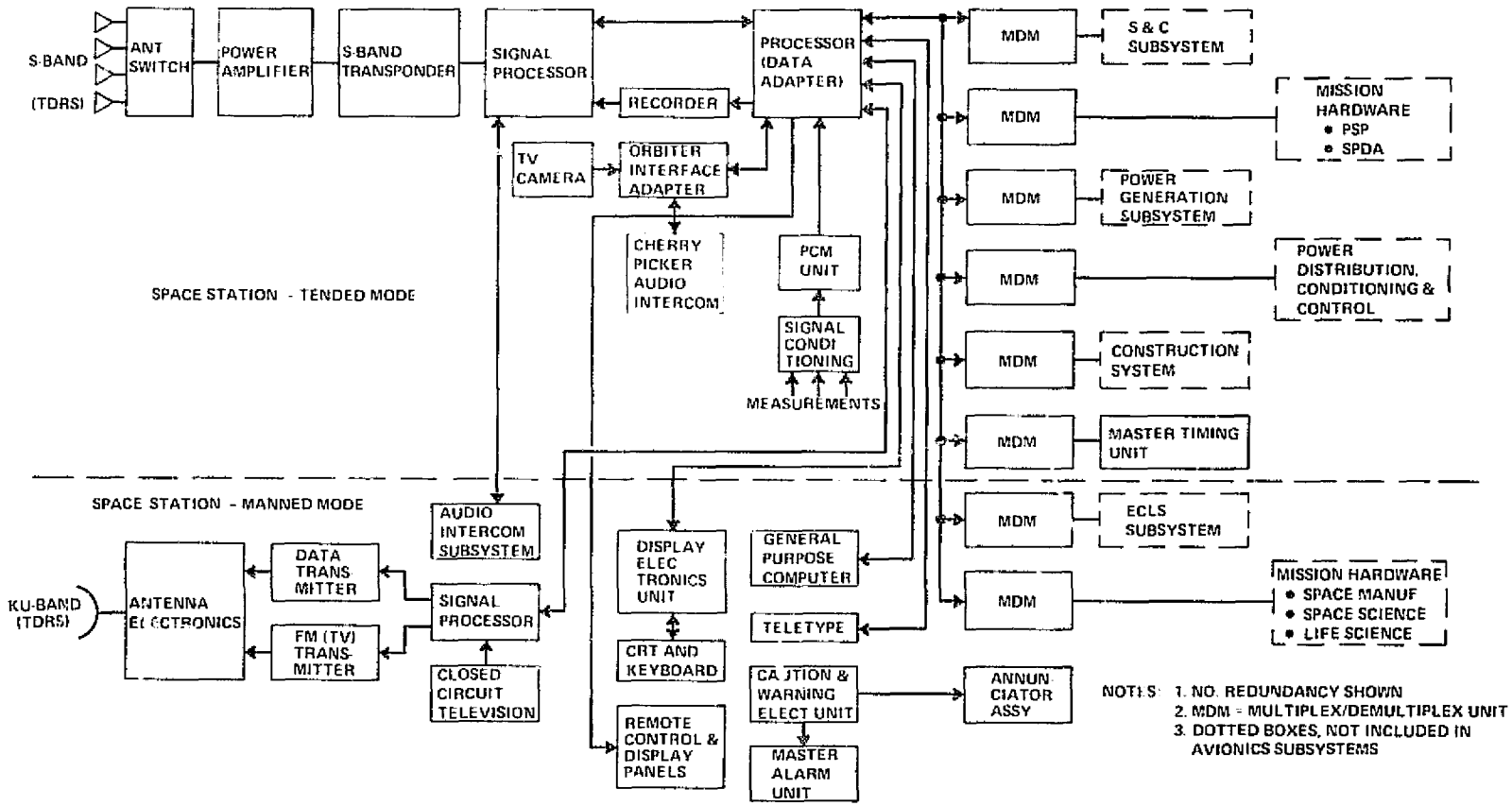
AVIONICS FUNCTIONAL BLOCK DIAGRAM



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G-409

FOLLOW-ON TASKS

- REFINE AVIONICS SUBSYSTEMS REQUIREMENTS
- UPDATE AVIONICS FUNCTIONAL CONFIGURATION

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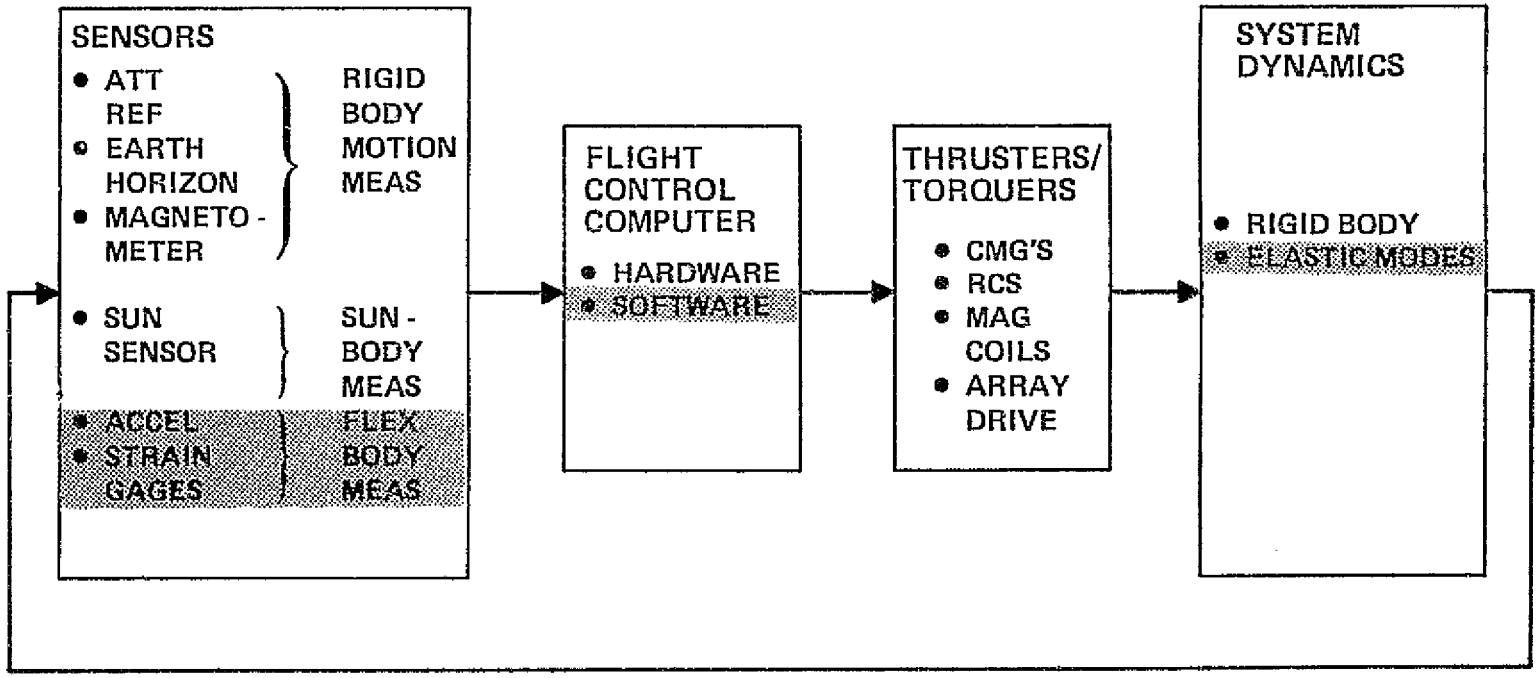
SPACE STATION FLIGHT CONTROL SUBSYSTEM

"FLEXIBLE FLIER" CONTROL ACCOMODATES SYSTEM FLEXIBILITY



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F-405

GROWTH CAPABILITY OF SPACE STATION FLIGHT CONTROL SUBSYSTEM (FCS)

- FCS HARDWARE PROVIDES SYSTEM FLEXIBILITY TO PERFORM ALL FLT CONTROL FUNCTIONS FOR WIDE RANGE OF STATION CONFIGURATIONS
- DIGITAL CONTROL ALGORITHM IN COMPUTER INCLUDES "GAIN SCHEDULING" FOR LARGE INERTIA CHANGES
- FLEX STRUCTURE STAB ATTAINED BY BENDING/ TORSION MODE MEASUREMENT INPUT TO KALMAN [illegible]RING CONTROL IN COMPUTER
- SELECTED COMPUTER POSSESSES CONSIDERABLE MARGIN FOR GROWTH OVER SKYLAB FCS COMPUTER

PARAMETER	SKYLAB	SPACE STATION
MEM CAPACITY (WORDS)	16K	32K
BITS/WORD (DATA)	16	16
OPER SPEED (KOPS)	67	450

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SPACE STATION SUBSYSTEM DEVELOPMENT DATA

SPACE STATION SUBSYSTEM	% DDT&E COST	% OFF-THE-SHELF	PROGRAM SOURCE
STRUCTURE (MODULES)	44.9	11	SPACELAB
STRUCTURE (OTHER)	13.6	3	STS
ENV. PROTECTION	5.5	0	—
EPS	7.0	35	SEPS
FLIGHT CONTROLS			
S & C	0.5	80	STS/FLEET SAT. ETC.
RCS	0.2	56	MARINER
AVIONICS			
COMM/TRACKING	2.8	56	STS
DATA MGMT.	12.7	60	STS
ECLS	7.0	30	RLSE
CREW ACCOMMODATIONS	5.8	38	STS/SKYLAB

SUBSTANTIAL USE OF OFF-THE-SHELF EQUIPMENT IN SPACE STATION PROGRAM

SPACE STATION/SHUTTLE INTERFACE IDENTIFICATION BY MODE

EVOLUTION OF SPACE STA/STS INTERFACES
- NO CHANGE IN FUNCT CATEG
- PROBABLE CHANGE IN FLOW RATE

SPACE STA SUBSYS	TENDED	MANNED	INTERFACE TO SHUTTLE	E	F	M
STRUCTURE	√	√	STA DOCK/ORB DOCKING ADAPTER			√
FLIGHT CONTROL	√	√	STA COMP/ORB COMPUTER	√		
EPS	√	√	POWER BUS CONNECTION	√		
AVIONICS – COMM	√	√	VOICE/VIDEO SIGNALS	√		
AVIONICS – DATA MGT	√	√	DATA SIGNALS	√		
ENVIRON. CONTROL	–	–	NONE			
THERMAL CONTROL	√	√	FLUID TRANSFER		√	
CAUTION & WARNING	√	√	SUBSYSTEM STATUS	√		

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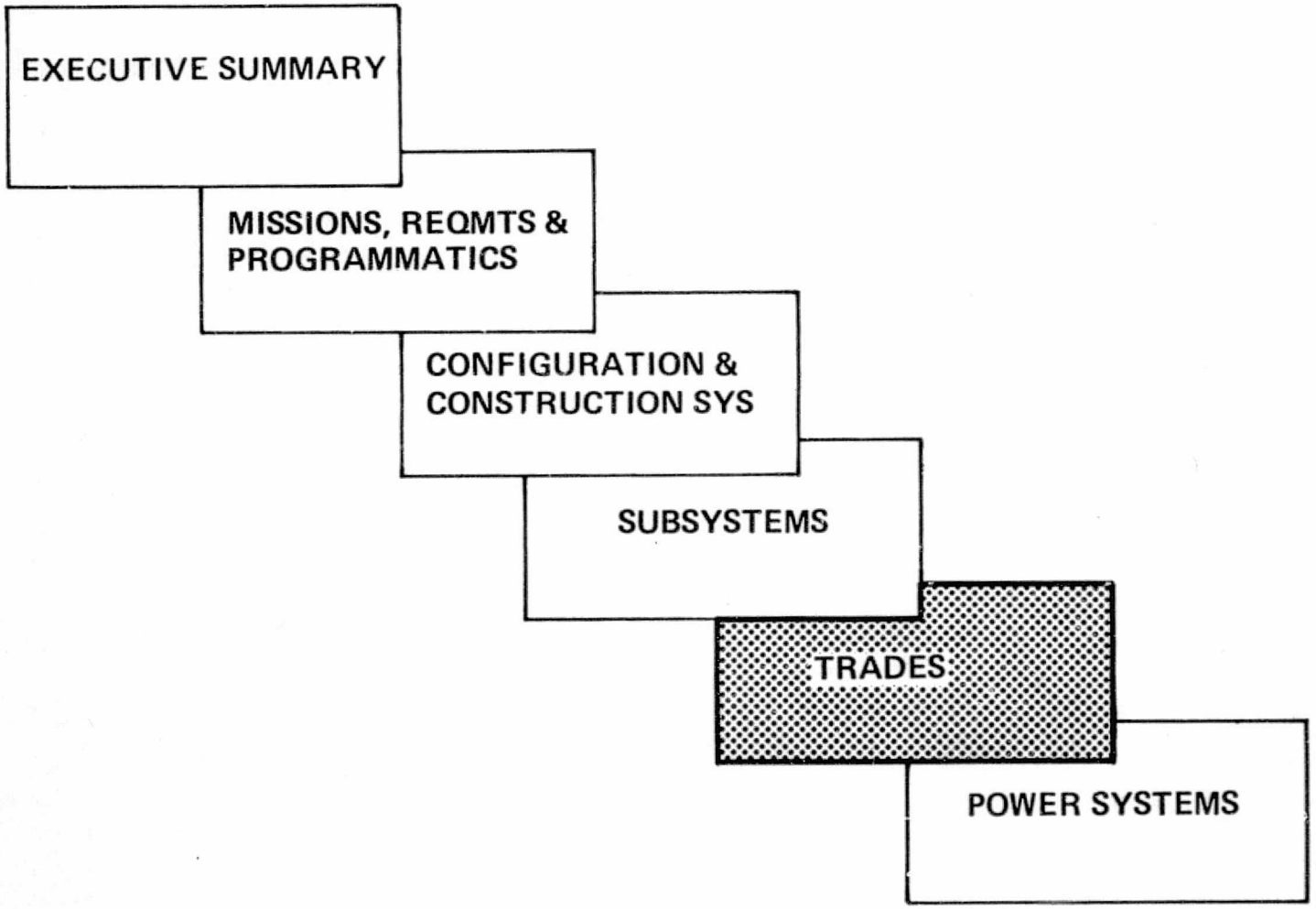
G-417

AGENDA SPACE STATION PROGRAM REVIEW MEETING
19 APRIL 1977



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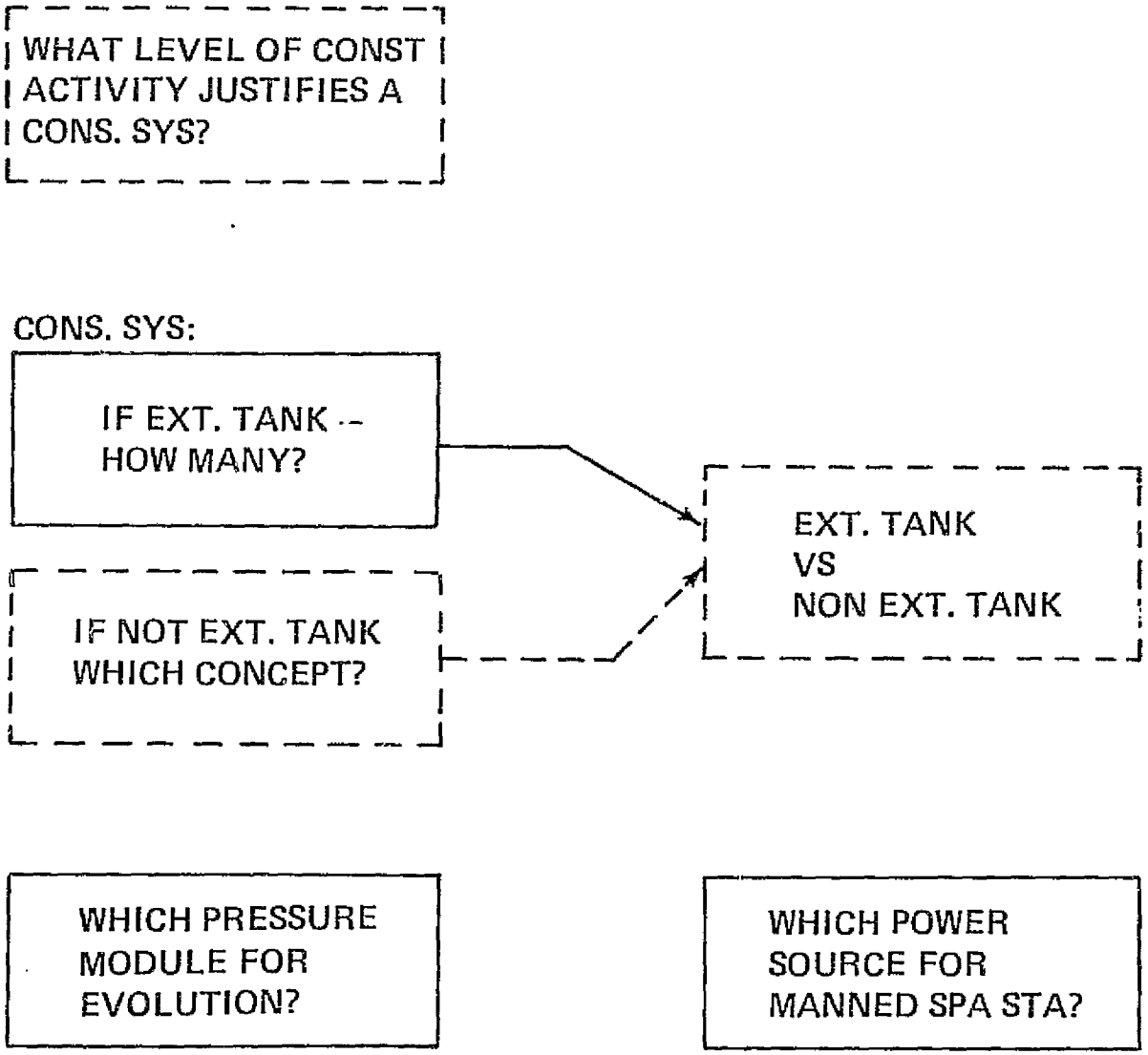
MAJOR SPACE STATION ISSUES/TRADES



SPACE STATION CONSTRUCTION FACILITY
– DOUBLE EXT. TANK SPINE

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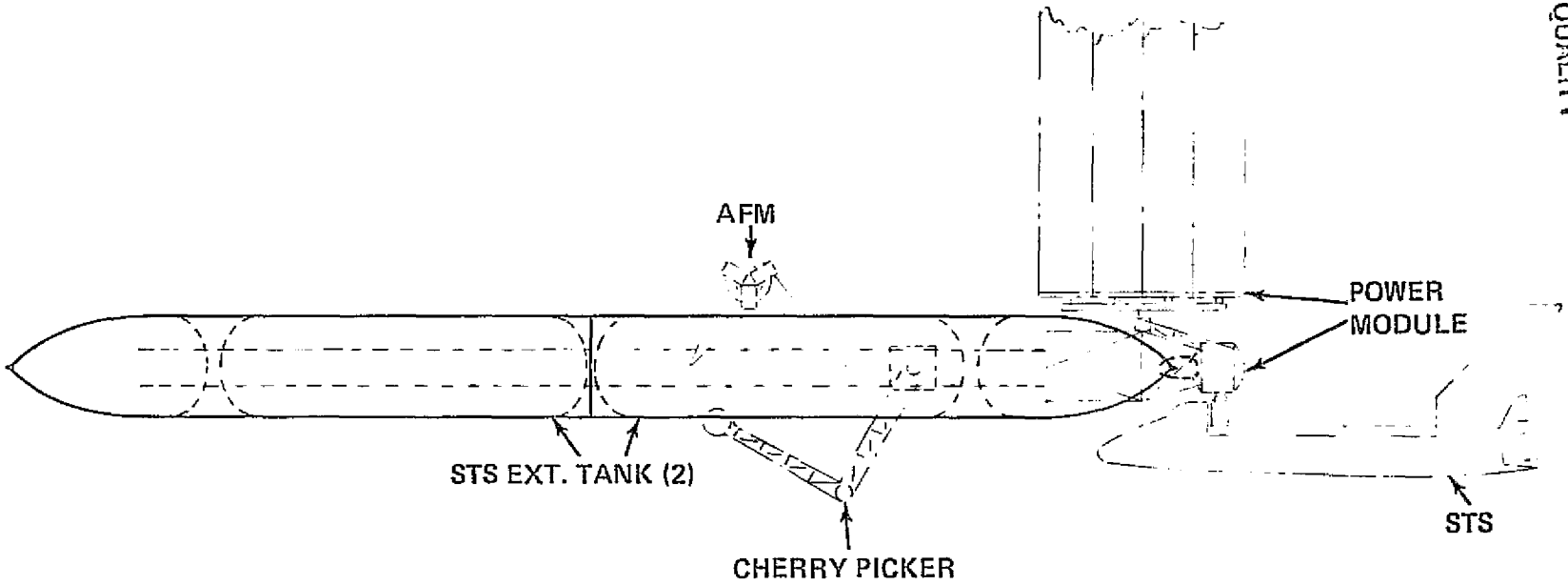

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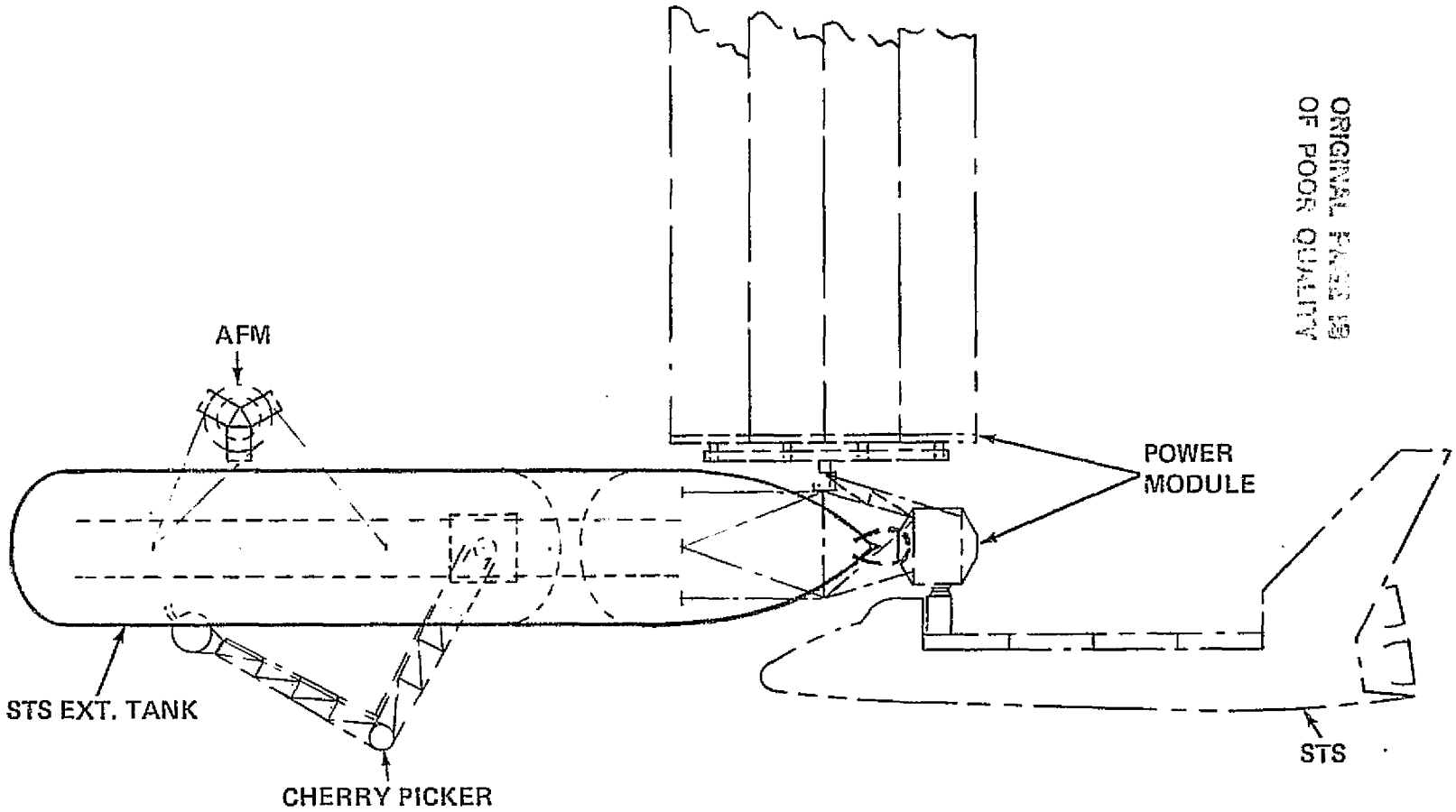
SPACE STATION CONSTRUCTION FACILITY
– SINGLE EXT. TANK SPINE



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SPACE STATION
SINGLE VS TWO EXT. TANKS CONSTRUCTION SPINE

– CHANGE TO SINGLE TANK
– PRESERVE OPTION FOR ADDING SECOND TANK

TRADE CRITERIA	SINGLE EXT. TANK	TWO EXT. TANKS	REMARKS
• GRAV. GRAD. & DRAG TORQUES	LOWER FREQUENCY	STIFFER	SEE CHART
• HYDRAZINE PROP. TO NULL DRAG ('84 TO '88)	15,420 Kg	23,130 Kg	
• P.L. PENALTY FOR TAKING EXT. TANK TO ORBIT	2463 Kg	4926 Kg	
• MATING TWO TANKS	√		
• CONSTRUCTION ACTIVITY		MARGINALLY EASIER	SEE CHART
• GROWTH – PRESS. MODULES	√	√	GROW TO MANNED SCB
– POWER	√	√	RELOCATE FROM PWR. MOD.
– COOLING		√	MORE AREA AVAILABLE
• EXTERNAL STOWAGE AREA		√	MORE AREA AVAILABLLE

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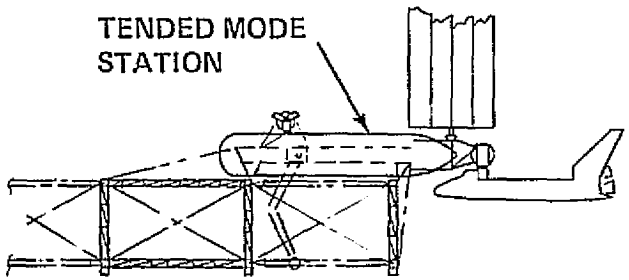
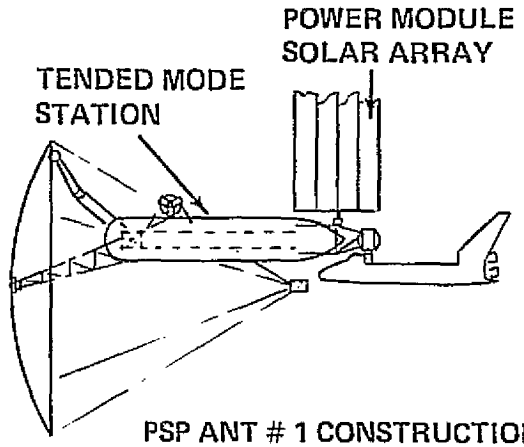
JG-431

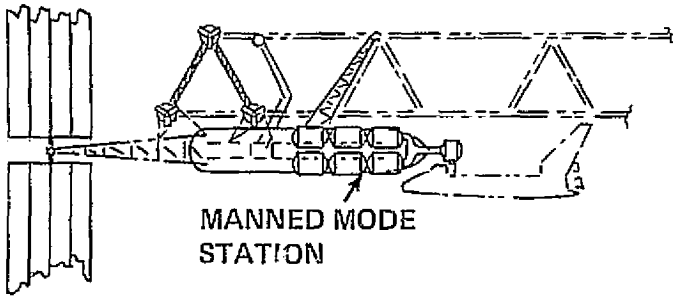
SPACE STATION CONSTRUCTION FACILITY
CONSTRUCTION WITH SINGLE EXT. TANK SPINE



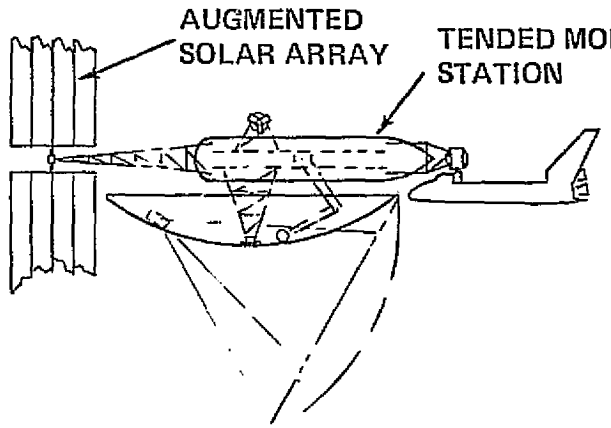
600 KW SPDA SOLAR ARRAY CONSTRUCTION



PSP ANT # 1 CONSTRUCTION



2.2 Mw SPDA CONSTRUCTION



PSP ANT # 1 CONSTRUCTION

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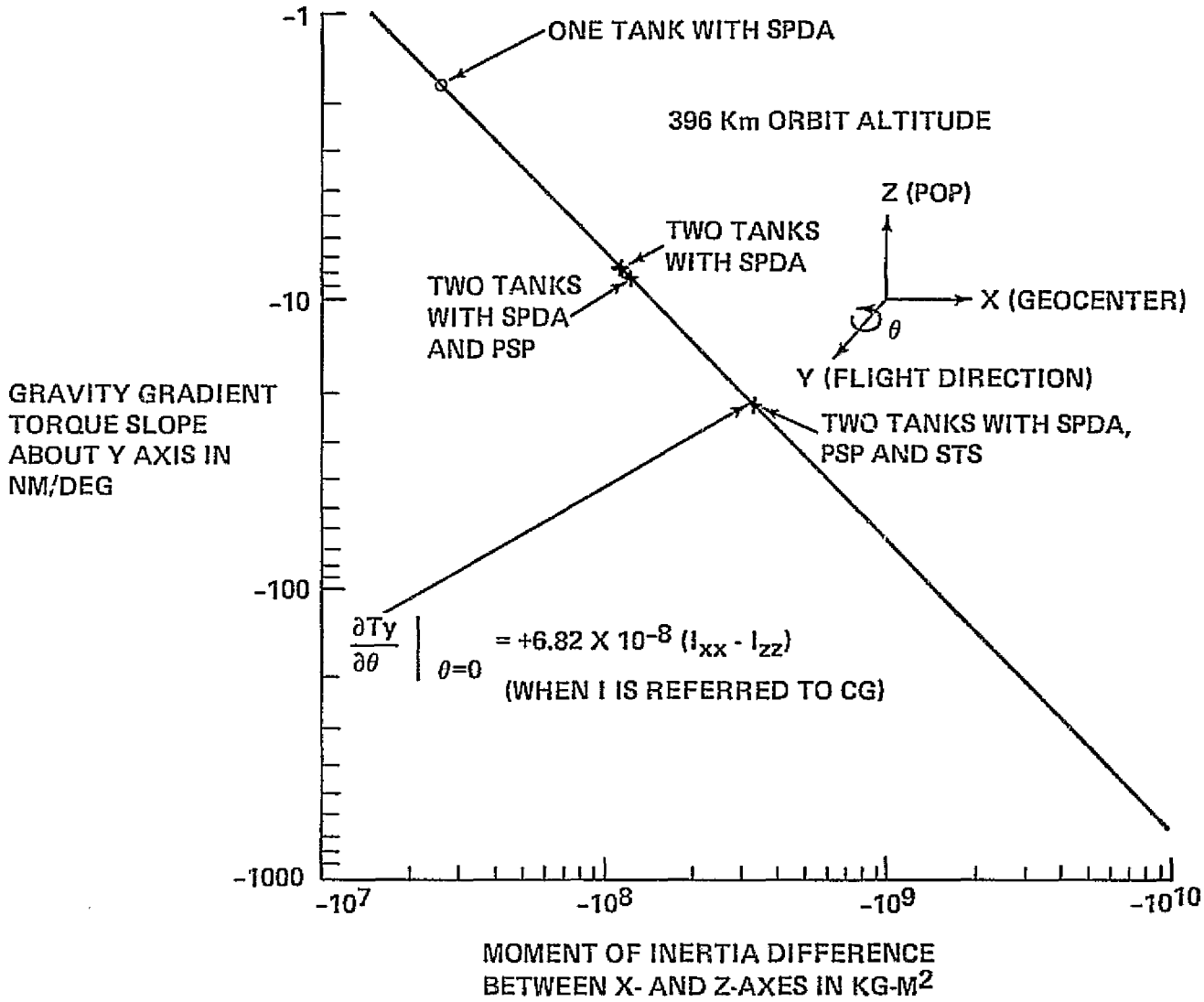
JG-438

SLOPE OF GRAVITY GRADIENT TORQUE VERSUS ANGULAR MOTION AS FUNCTION OF MOMENT OF INERTIA DIFFERENCE



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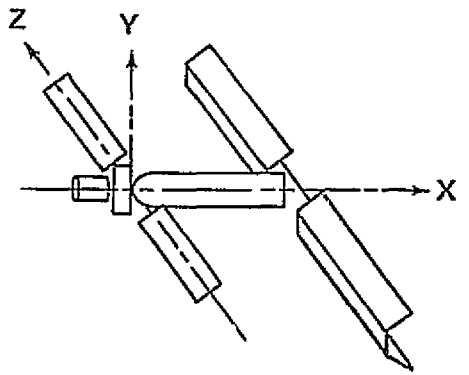
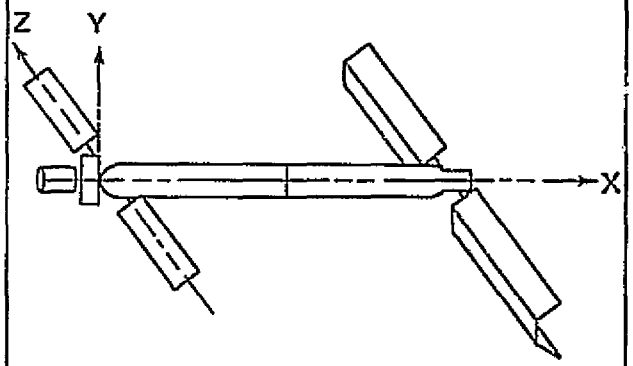
F-401

SPACE STATION STABILIZATION TORQUES FOR 396 KM/ 28.5° ORBIT

	ONE TANK CONFIG			TWO TANK CONFIG		
						
AXIS DIRECTION	T_x GEOCEN	T_y POP	T_z FLIGHT	T_x GEOCEN	T_y POP	T_z FLIGHT
GRAV GRAD TORQUE — NEWTON METERS/DEG	0	-1.8	-1.6	0	-8.2	-8.0
AERO DRAG TORQUE — NEWTON METERS	0	-2.5	—	0	-4.4	—

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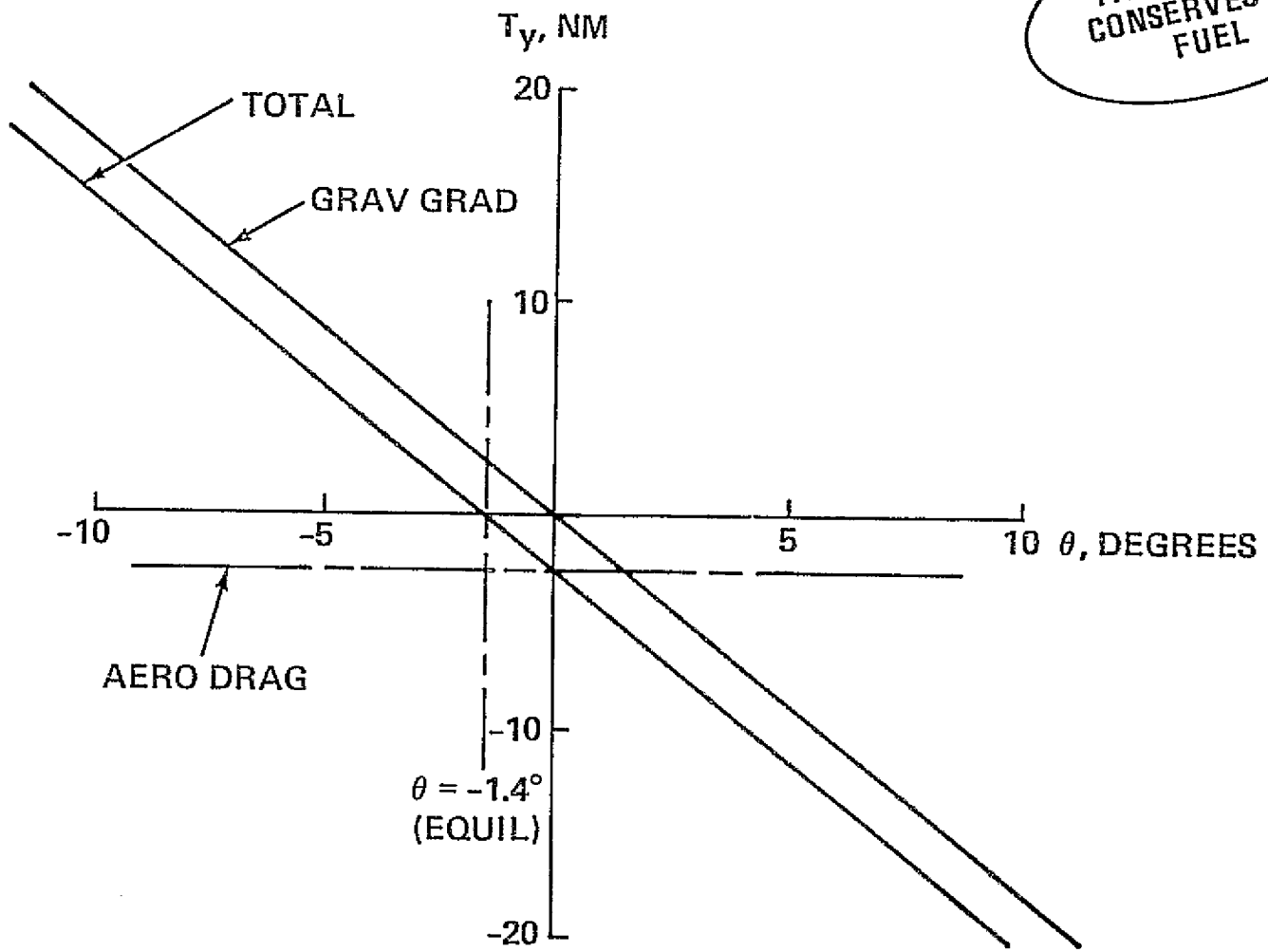
F-402

GRAVITY GRADIENT AS A STABILIZING TORQUE FOR SINGLE TANK SPACE STATION

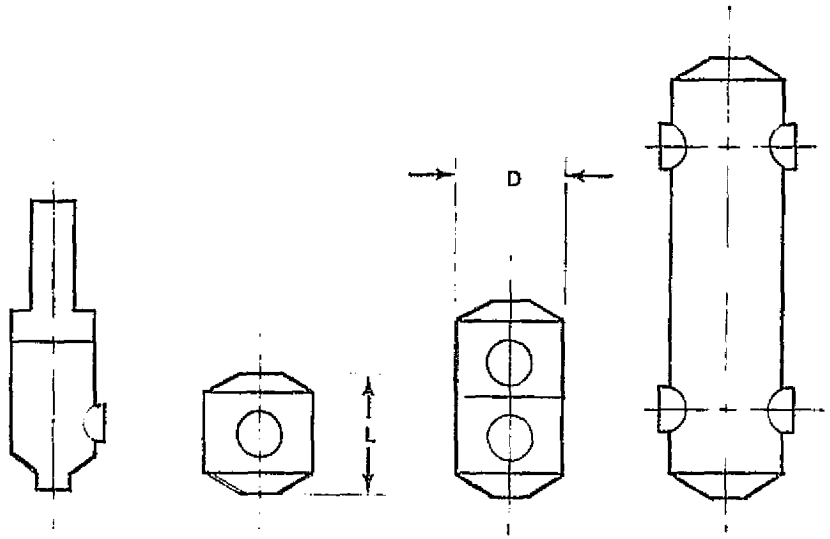
PASSIVE STAB CONSERVES RCS FUEL



GRUMMAN

F-403

PRESSURIZED VOLUMES TRADEOFF



	MDA & A/L	SHORT SPACELAB	LONG SPACELAB	NEW MODULE
L, m	10.62	4.27	6.96	15.75
D, m	3.04/1.68	4.06	4.06	4.06
INT VOLUME, m^3	50	38	75	167
AVAIL. EQUIP. VOL, m^3 AVAIL. HABIT. VOL	13 M^3 0	18 0	36	70
AVAIL. PASSAGE VOL, m^3	17	9	18	55
OPERATING PRESS., psi	5	14.7	14.7	14.7
NO. BRANCHES AVAIL.	1	1	2	4-5
DOCKING CAPABILITY	YES (APOLLO TYPE)	NO	NO	YES (INTERNATIONAL DKG)
MODS REQD	MIN-DKG & EQUIP. EXTENSIVE–14.7 PRESS	MED-DKG & DKG LOADS	MED-DKG & DKG LOADS, BRANCHES	NONE

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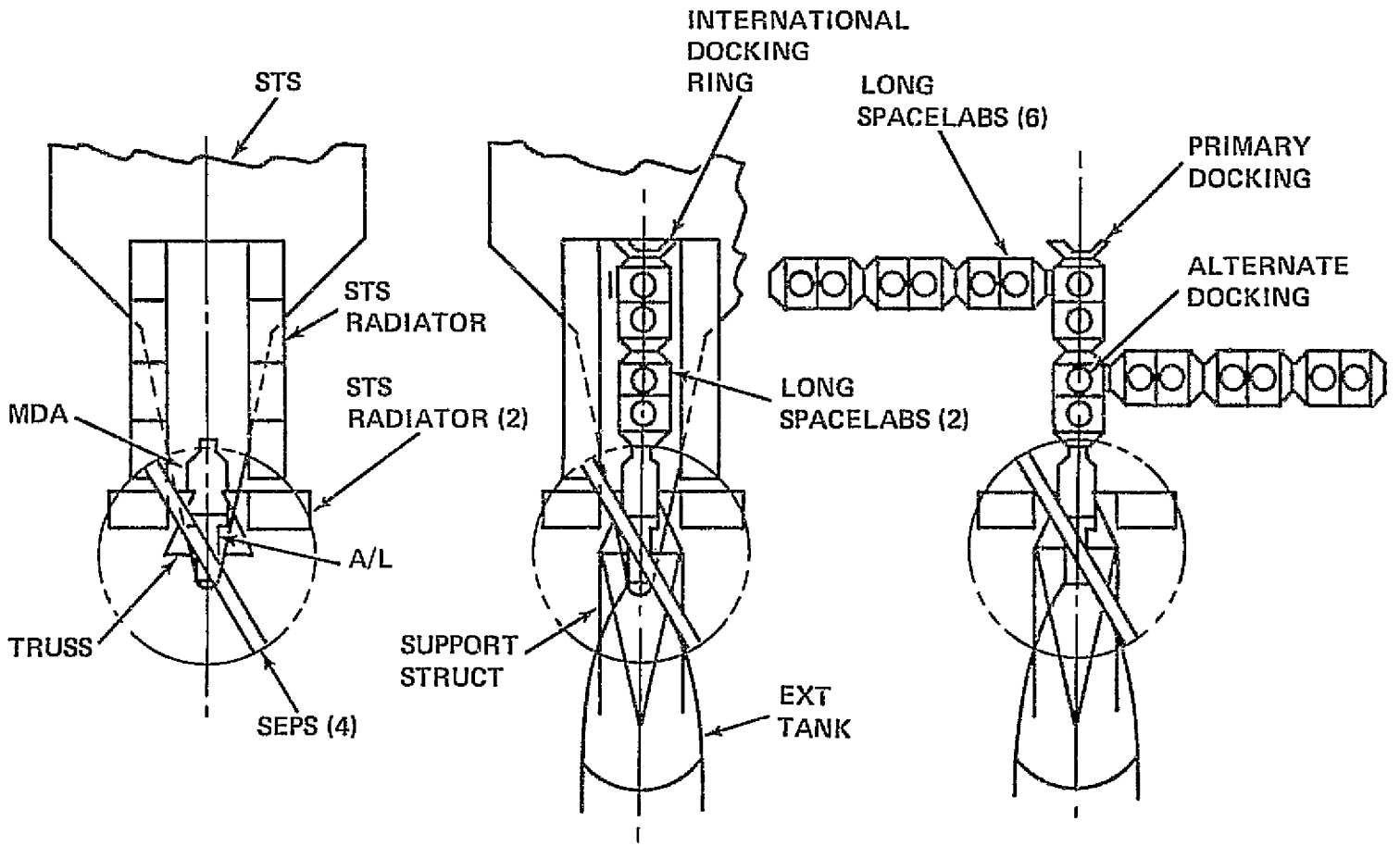
GRUMMAN

JG-406

SKYLAB MDA/AL BUILD-UP CONFIGURATION



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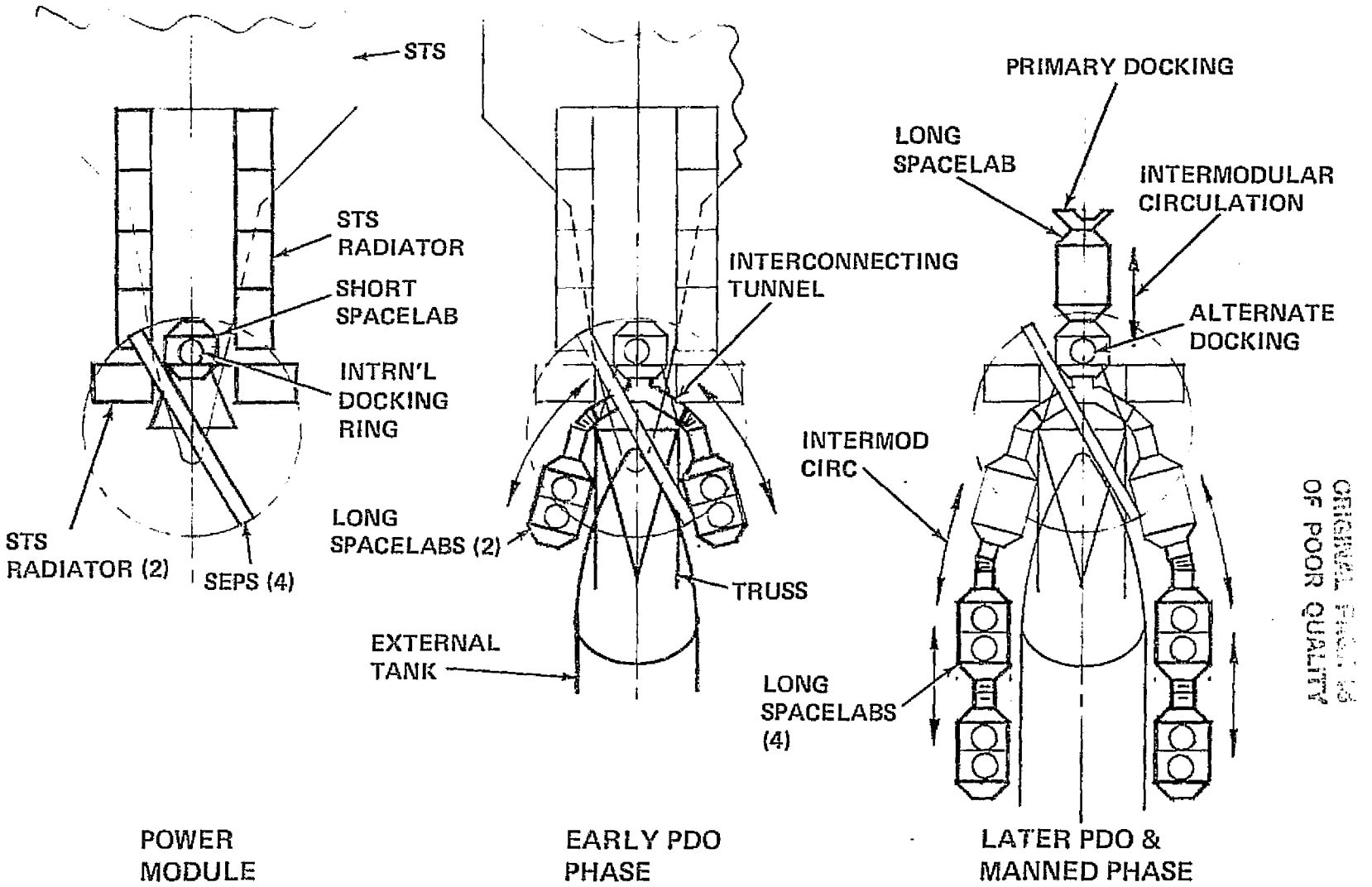
JG-407

SPACELAB BUILD-UP CONFIGURATION



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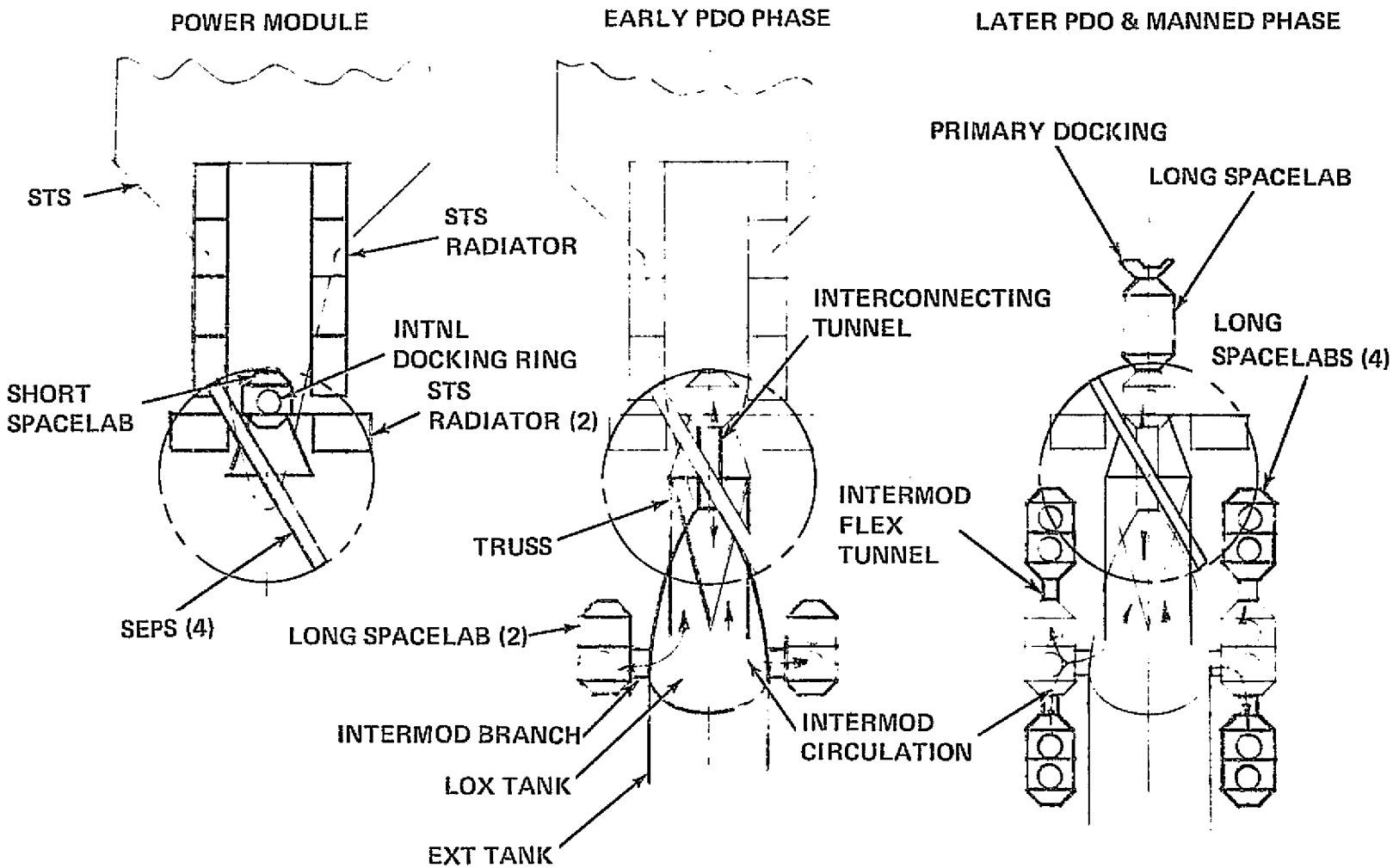
JG-414

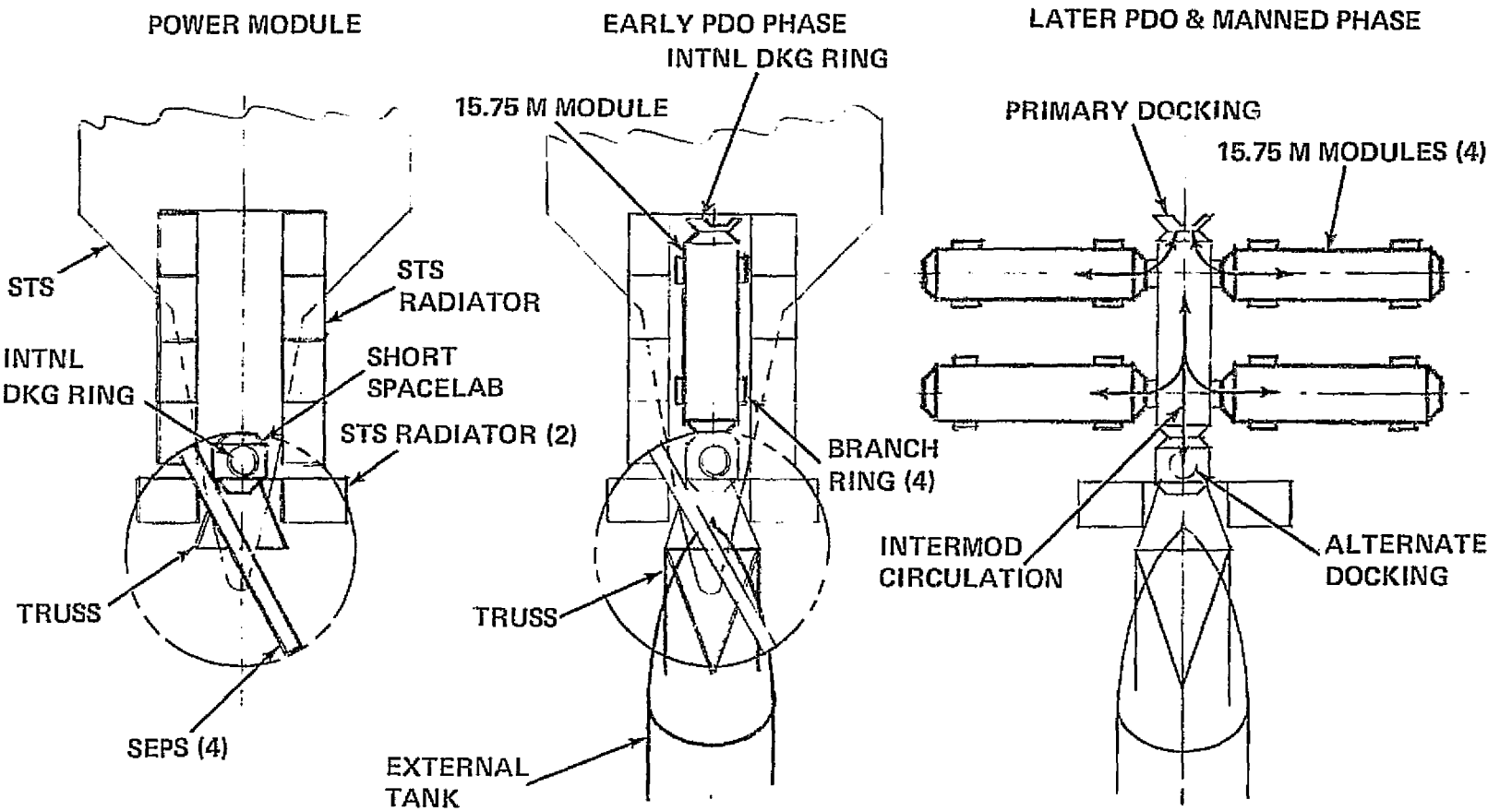
SPACELAB BUILD-UP CONFIGURATION (USING LOX TANK FOR INTERMODULAR CIRCULATION)



GRUMMAN

JG-424

15.75 m MODULE BUILD-UP



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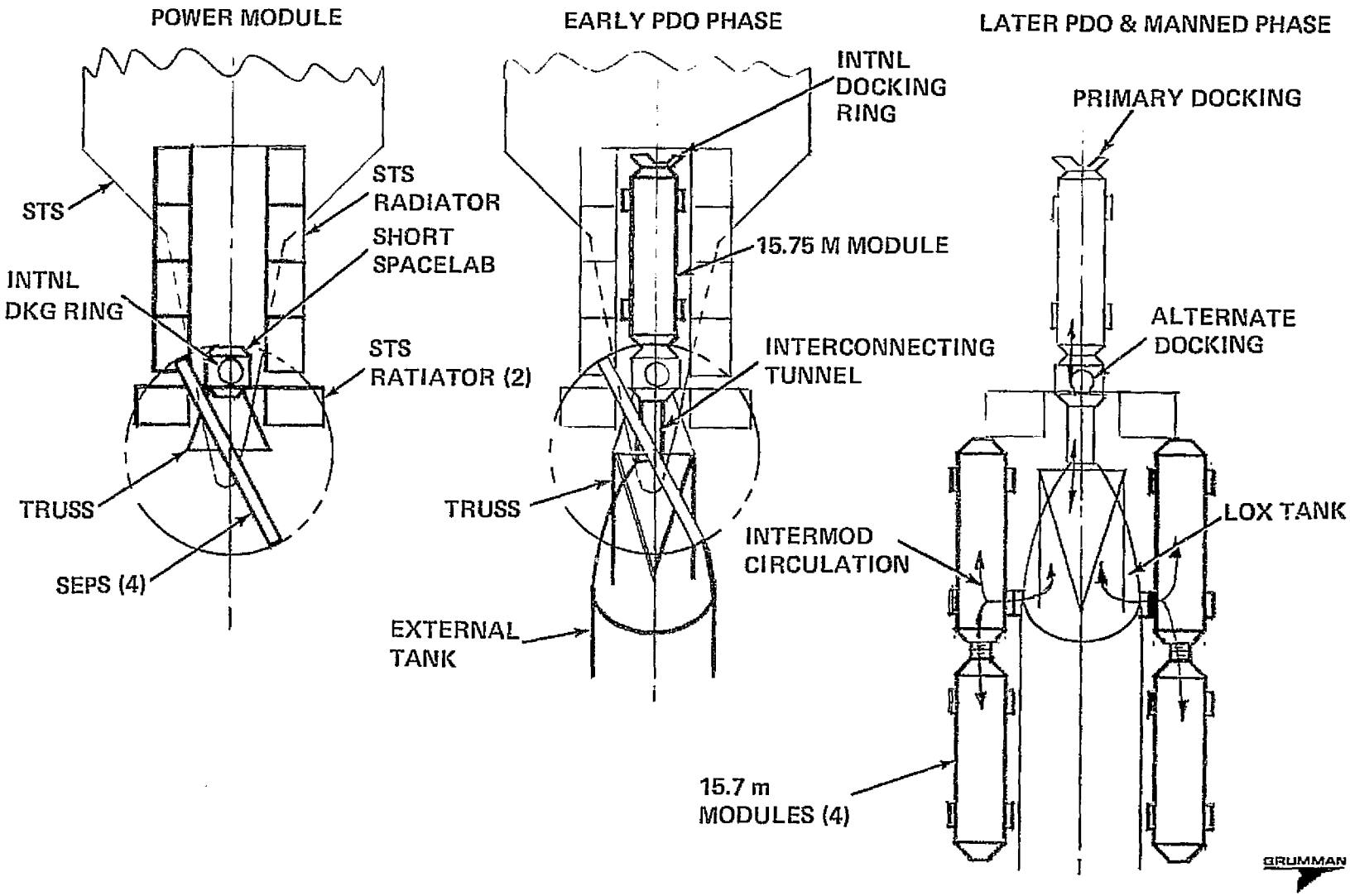
GRUMMAN

JG-425

15.75 m MODULE BUILD-UP CONFIGURATION (USING LOX TANK FOR INTERMODULAR CIRCULATION)



JG-432

COST TRADE – LONG SPACELAB (7M) VS. NEWLEY DEVELOPED MODULE (15.7511)

(COSTS IN MILLION DOLLARS)

TYPE OF MODULE	ORBIT	NO. OF MODULES	DDT&E	PRODUCTION COSTS		FLIGHTS		TOTALS	
				PURCHASE	SUBSYSTEMS	STS	OTV	FOR ORBIT	FOR SYSTEM
NEWLY DEVELOPED MODULE (15.75M)	LEO	4	170.5(3)	–	349.0	80	(1)	599.5	
	GEO	2	5.0(3)	–	177.5	40	(1)	222.5	822.0
LONG SPACELAB MODULE (7M)	LEO	7	31.5(4)	77.0(2)	282.4(5)	70	(1)	460.9	
	GEO	4	18.0(4)	44.0(2)	139.5(5)	40	(1)	241.5	702.4

NOTES

(1) MASS TRANSPORTED TO GEO IS SAME FOR 15.75M & 7M MODULES & THEREFORE NOT A TRADE ISSUE

(2) PURCHASE PRICE OF STRUCTURAL/THERMAL SPACELAB MODULE ESTIMATED @ 11M EACH

(3) DDT&E COSTS FOR STRUCTURE, THERMAL PROTECTION SYSTEM & TOOLING & MAJOR TEST ARTICLES ONLY – OTHER SUBSYSTEMS COSTS EQUAL.

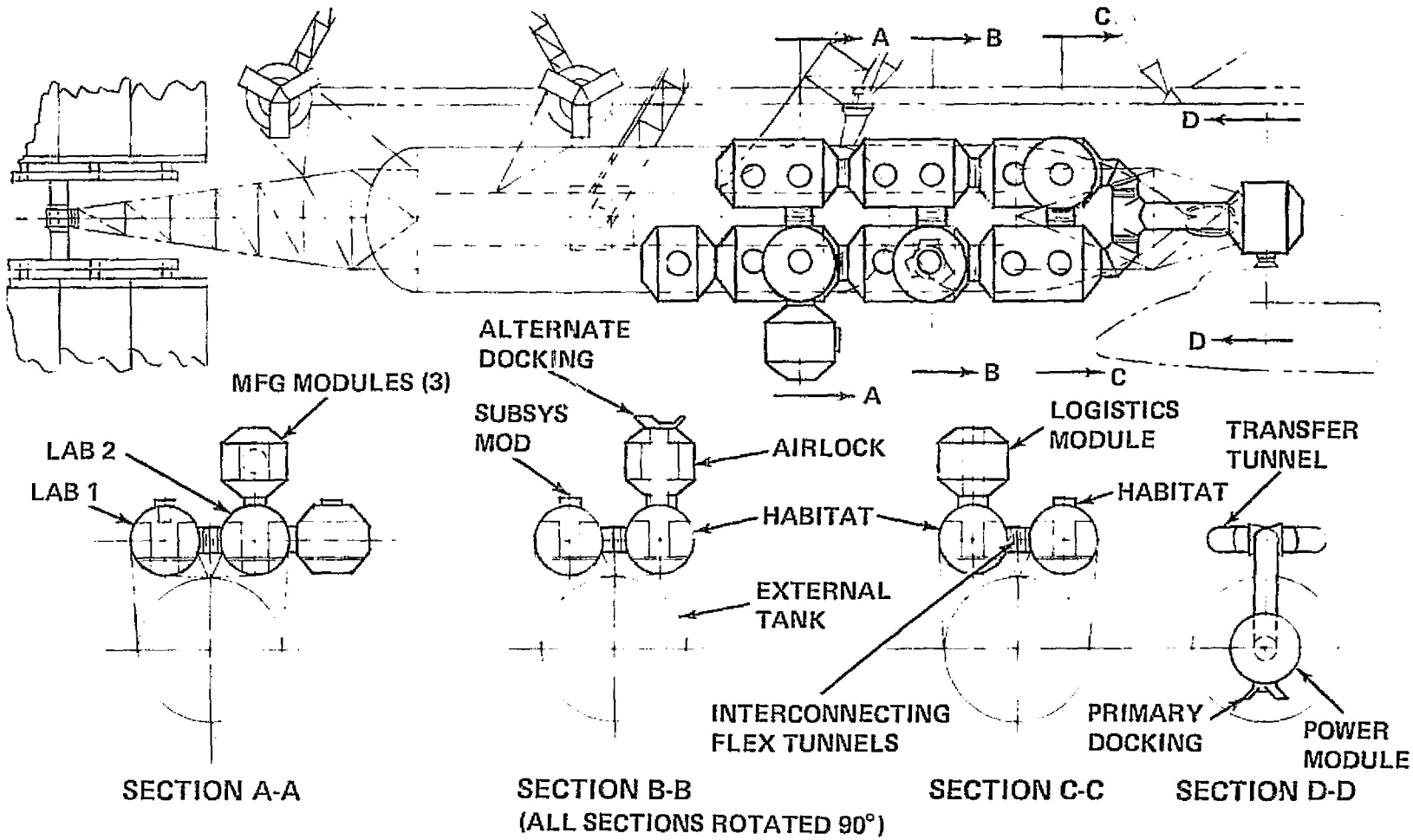
(4) COSTS FOR MODIFYING SPACELAB STRUCTURE & TPS TO ACCOMMODATE DOCKING, DOCKING LOADS, BRANCHES & WINDOWS

(5) INCREASE 25% OVER 15.75M VALUES TO ACCOUNT FOR INCREASED NO OF MODULES OUTFITTED

GRUMMAN

JG-465

CANDIDATE PRESSURE VOLUME CONFIGURATION – SHORT & LONG SPACELAB MODULES



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JG-415